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AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

A Bibliography of the Electrically Exploded Conductor Phenomenon, Fourth Edition

WILLIAM G. CHACE
ELEANOR M. WATSON

OFFICE OF AEROSPACE RESEARCH
United States Air Force

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Abstract

This bibliography includes abstracts of reports on the exploding conductor (exploding wire) phenomenon published from 1774 through 1966. There is also some coverage of important papers in adjacent areas of spectroscopy and instrumentation. Arrangement is by subject group, alphabetically by authors.

Preface to the Fourth Edition

It was not anticipated that a fourth edition would be published after a single supplement to the third. However, since the Third Edition became completely exhausted shortly after the appearance of the supplement, it became necessary to prepare this new edition.

No change has been made in the general plan of the work as explained in the Introduction.

Coverage in areas other than Exploding Wires (Section E) and Exploding Foils and Films (Section U) is perhaps less thorough than in earlier editions. Most of these fields are covered by other good bibliographies, which should be consulted for more thorough coverage.

There has been, however, no relaxation of our original attempt to cover the major field completely. It is still our aim to include every publication on exploding conductors, even science fiction! (Slobodkin, E-186). This edition covers the literature through the year 1966.

The authors wish to thank those who have pointed out errors and omissions in previous editions. It is our earnest hope that any lapses in the present edition will be promptly reported to us. Only by this assistance from users can the number of errors and omissions be kept at a minimum.

Extract from Preface to the First Edition

In connection with a fundamental study of the Exploding Wire Phenomenon (E. W. P.) being conducted by this laboratory, a search of the literature was undertaken. It was originally intended purely as background for our work. However, conversations with others working on E. W. P. and related problems indicated so much interest, that arrangements were made for this informal publication of the bibliography before the research paper to which it would normally be an appendix.

At the time this work was started, no exhaustive bibliography of E. W. P. was available. Shortly before it was completed William M. Conn's paper in the Z. angew. Phys. (see reference E-70) appeared with its excellent bibliography. It was decided to go ahead with this publication, however, since no English bibliography was available, and it was hoped the annotations might prove valuable.

The abstracts are from various sources. Most are original, from reading of the articles, but some were taken from abstract journals, — Physics Abstracts, Transactions of IRE, Chemical Abstracts, etc. Unfortunately since publication of the notes was not originally planned, no record was kept of sources so credit cannot be given in individual cases.

Contents

A Bibliography of the Electrically Exploded Conductor Phenomenon Fourth Edition

INTRODUCTION

The general bibliographic arrangement and the journal abbreviations are, as recommended by the American Institute of Physics, those of Chemical Abstracts.

The bibliography is arranged in subject groups, each with a characteristic letter. Within the group, arrangement is (1) alphabetical by authors, (2) inverse chronological for articles by any one author.

In order not to repeat the abstract, each article is assigned to a subject group and given a letter characteristic of the group. The abstract appears in this group. When the article refers to other subjects, the reference, but not the abstract is included in the regular sequence in all pertinent groups. Its code group (which of course, is the same as before) leads the user back to the abstract.

For example: SMITH, S., Astrophys. J. 61, 186-203 (1925) is assigned code E-187 since E is the E. W. P. section and the article is principally about E. W. P. However, Smith discusses apparatus hence E-187 appears in proper alphabetical sequence in the apparatus (A) section. Theory is considered so E-187 is in Section S (theory). Spectroscopy is also an important topic in this paper hence E-187 is listed as well in the section on spectroscopy (P).

It is hoped this system of cross references will make it easy for the user to locate any article.

Titles are given in the original language, except Russian where typography made this impossible. A translation is also given for each title.

(Received for Publication 8 August 1967)

APPARATUS – Section A

L-1 BARTELS, H. and EISELT, B., "Über ein einfaches Verfahren zur kinematographischen Aufnahme schnell verlaufender Vorgänge," Optik 6, 56-58 (1950) (A Simple Method for Cinematographic Photography of Rapidly Occurring Processes)

A-1 BELLASCHI, P. L., "Heavy Surge Currents — Generation and Measurements," Trans. Am. Inst. Elec. Engrs. 53, 86-94 (1934)

A quantitative discussion of surge-current generators. Some recommendations for measurements on these generators. Formula for current necessary to fuse a conductor.

A-2 BENNETT, F. D. and SHEAR, D. D., "Visualization of Cylindrical Shock Waves," B. R. L. Memo Report 1199 (March 1959)

The authors offer an improvement in Bennett's mirror back-lighted method of rendering shock waves visible from an E. W. Mirror is replaced with an array of shiny wires. Used No. 16 tinned copper wires in side-by-side contact.

A-3 BENNETT, F. D. and SHEAR, D. D., "Visualization of Cylindrical Shock Waves," Phys. Fluids 2, 338-339 (1959)

(See A-2)

A-4 BENNETT, F. D., SHEAR, D. D., and BURDEN, H.S., "Streak Interferometry," J. Opt. Soc. Am. 50, 212-216 (1960)

(See A-5)

A-5 BENNETT, F. D., SHEAR, D. D. and BURDEN, H. S., "Streak Interferometry," B. R. L. Report 1080 (September 1959)

The fringe method of examining shock waves has been combined with a Mach-Zender interferometer to allow study of transient axisymmetric flow. Apparatus is described and results are illustrated and analyzed.

A-6 BREIDENBACH, H. L., Jr., "A Fractional Microsecond X-ray Pulse Generator for Studying High Explosive Phenomena," Rev. Sci. Instr. 20, 899-903 (1949)

Discussion of apparatus.

Q-4 BROADBENT, T. E., "The Breakdown Mechanism of Certain Triggered Spark Gaps," Brit. J. Appl. Phys. 8, 37-40 (1957)

A-7 CHACE, W. G. and CULLINGTON, E. H., "Instrumentation for Studies of the Exploding Wire Phenomenon," Instrumentation for Geophysical Research No. 7, AFCRC-TR-57-235 (1957)

Discussion of the theory and problems of E. W. P. instrumentation with some data on solutions to problems. Detailed description of control methods and some measuring equipment.

A-8 CNARE, E. C., "An Exploding Wire as a Fuse for the LASL Capacitor Bank - Zeus," Sandia Corp. SC-4324 (TR), TID-4500 (14th Ed) (1959)

A study of the optimum wire for a capacitor bank fuse. By using a tube around the wire, better results are obtained. Copper wire proves to be better than lower resistivity wires. The theoretical study is from consideration of Sandia's "action" function.

Q-6 CULLINGTON, E. H., CHACE, W. G. and MORGAN, R. L., "Lovotron - A Low Voltage Triggered Switch Gap," Instrumentation for Geophysical Research No. 5, AFCRC-TR-55-227 (1955)

J-2 FAYOLLE, P. and NASLIN, P., "Photographie Instantanée et Cinematographie Ultra-Rapide," Revue d'Optique, Paris, (1950) (Instantaneous Photography and High Speed Cinematography)

A-9 FERRARI, G., "Condensatori a Carta 'Induttivi' e 'Antiunduttivi'," Ducati-Divisione Reçerche-Laboratorie, Condensattori a Carta - EC - 1 (no date) (Inductive and Non-inductive Paper Condensers)

Inductance of condensers as effected by type of construction.

A-10 FOITZIK, S., "Versuche mit grossen Stosstromen," Electrotech. Z. 60, 89-92, 12?-133 (1939) (Experiments with Heavy Surge Currents)

Discussion of the design of a surge current generator and experiments performed with it. Action on metal conductors discussed.

E-94 GOL'TS, E. YA and SADKOVICH, N. P., "Electric Explosion of Mercury Jet," Zh. eksp. teor. fiz. (Pis'ma) 2, 463-466 (1965) Trans. in JETP Letters 2, 288-289(1965)

M-9 HALPIN, W. J. and HENDRICKS, R. E., "The Use of Pressure Bars and Plates for the Investigation of Shock Waves from Electrically Exploded Wires," Sandia Tech. Memo SCTM 39-60 (51) (1960)

A-11 JANES, G. S. and KORITZ, H., "High Power Pulse Steepening by Means of Exploding Wires," Rev. Sci. Instr. 30, 1032-1037 (1959) (Also AVCO Res. Lab. Res. Rep. 50) (1959)

Extremely fast rise time produced by charging the transmission lines thru the E. W.'s and then transferring this to the load when the wires blow. Details of the device and apparatus for preparing the multiple wire fuse elements are included.

A-12 KAPITZA, P., "Further Developments of the Method of Obtaining Strong Magnetic Fields," Proc. Roy. Soc. (London) A115, 658-683 (1927)

A rotating generator of special construction as a high current, pulsed energy source.

D-3 KAPITZA, P., "A Method of Producing Strong Magnetic Fields," Proc. Roy. Soc. (London) A105, 691-710 (1924)

M-13 KOTOV, Yu, A. and MEL'NIKOV, M. A., "Recording Shock Waves and Exploding Wire Characteristics," Elektronnaya obrabotko materialov No. 3, 28-32 (1966)

A-13 LOGINOV, V. A., "Set-up for Studying Electron Absorption Spectra by Electrical Bursting of Wires Immersed in Water," Pribory i tekh eksper. No. 1, 171-173 (1964)

Description of apparatus.

A-14 MARSHAK I. S., "On the Practical Application of Exploding Wires," Optika i Spectroskopia 10, 801-804 (1961) (Trans. in Optics and Spectroscopy 10, 424-426 (1961)

Principle of E.W.P. briefly discussed. Apparatus for continuous loading of wire-fiberglass thread treated with enamel laquer and wound with 125 micron W wire. Thread passes from a reel between two tubular electrodes wound up on second reel. Passes through at approximately 30 cm/sec. Flash interval 1-5 sec.

X-32 McFARLANE, H. B., "A High-Voltage, Quick-Acting Fuse to Protect Capacitor Banks," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 324-344

A-15 PARK, J. H., "Design Data for Coaxial Shunt and Coaxial Inductor," J. Research Natl. Bur. Standards 39, 191-212 (1947)

Shunt for coaxial measurements of very high surge currents. Inductor to measure di/dt.

H-6 PARK, J. H. and CONES, H. N., "Puncture Tests on Porcelain Distribution Insulators Using Steep-front Voltage Surges," Trans. Am. Inst. Elec. Engrs. 72, 1 (1953)

A-16 PREUSS, L. E., "Image Formation of the Rapid Vaporization of Metal Filaments by the Sensitization and Autoradiographic Methods," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, (1959), p. 288-306

Evaporation of metals may be studied by a "pin hole" evaporation camera. The deposit is intensified by depositing on it another metal or by including in the original sample a radioactive tag and using autoradiography.

A-17 REITHEL, R. J. and BLACKBURN, J. H., "Method of Terminating the Energy Input to an Electrically Exploded Wire," Rev. Sci. Instr. 31, 464 (1960)

Triggered gaps across coax lines to crowbar the circuit. Resistance was 0.32 ohm. Inductance 0.45 μh. Used on Au wire. Cold resistance 0.042 ohm.

E-183 SCHERRER, V. E., "The NRL – AFSWP Exploded Wire Research Program," Exploding Wires Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 118-134

T-5 SLACK, C. M. and DICKSON, D. C., "One-Millionth-Second Radiograph and Its Application," Proc. Inst. Radio Engrs. 35, 600-606 (1947)

E-187 SMITH, S.; "A Study of Electrically Exploded Wires, Rotating Mirror Spectrograph," Astrophys. J. 61, 186-203 (1925)

A-18 TROLAN, J.K., CHARBONNIER, F. M., COLLINS, F. M. and GUENTHER, A. H., "A Versatile Ultrafast Pulsed Power System," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 361-389

A unique pulse power system has been constructed to generate very high-energy-density plasmas for the specific purpose of determining the electrical, thermodynamic, and radiative properties of materials at high temperatures. The system has been designed to provide a very fast rising pulse (< 8 nsec) of short duration (~50 nsec) for the condition of a constant and matched 4.7 ohm load impedance. System design features discussed include the paralleling of 15 synchronized 320 kV Marx surge generators coupled to an evacuable transducer chamber by means of a multiple-input matched impedance transmission line.

A-19 TUCKER, T. J., "Square-Wave Generator for the Study of Exploding Wires," Rev. Sci. Instr. 31, 165-168 (1960)

Description of a coaxial cable energy storage system, 100 kv, 2000 amp, 3 μsec duration pulse, with square wave form. Allows many analyses to be algebraic rather than nonlinear. Current and voltage coaxial measuring systems are described. Storage cable is 1000 ft. of RG 17/u.

A-20 WALBRECHT, E. E., "A Reliable Three-Channel Delayed Wire Exploder Unit," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 315-322

A delay and control circuit particularly designed for use in connection with E.W.'s.

Section A

A-21 WURSTER, W. H., "High Speed Shutter for Spectrographs," Rev. Sci. Instr. 28, 1093-1094 (1957)

Uses exploding lead wire to blow a "flap" made of scotch tape over the opening. Closes in 5 μsec.

A-22 ZAREM, A. M. and MARSHALL, F. R., "A Method for Measuring Very High Speed Transient Currents," Rev. Sci. Instr. 20, 133-134 (1949)

Description of a one turn magnetic deflection coil of sheet copper placed directly on the neck of a cathode ray tube, and a current transformer to reduce current to suitable value. Formulas are given for calculation of the characteristics of the current transformer.

E-220 ZAREM, A. M., MARSHALL, F. R. and POOLE, F. L., "Transient Electrical Discharges: Disintegration of Small Wires," Phys. Rev. 72, 158 (1947)

ARCS—Section B

Q-1 Anon, "5,000,000 - Ampere Arc," Radio-Electronics 31, 45 (September 1960)

P-1 ANDERSON, J. A., "Spectral Energy-Distribution of the High-Current Vacuum Tube," Astrophys. J. 75, 394-406 (1932)

N-2 BLOXSOM, D. E., "Production of High Temperature, Moderate Pressure Gases by Means of Electric Spark Discharges," Arnold Eng. Dev. Cent. AEDC-TN-56-17 (1956)

B-1 COBINE, J. D. and BURGER, E. E., "Analysis of Electrode Phenomena in the High-Current Arc," J. Appl. Phys. 26, 895-900 (1955)

Analysis of 100 amp., 60 cps arcs from energy balance point of view. Major energy loss due to evaporation. Graphs: (1) rate of evaporation of metals vs. temperature, (2) heat flow from surface vs. temperature.

B-2 DIEKE, G. H., "Study of Variations in Light Sources as They Affect Spectroscopy," ASTM Tech. Pub. 76, 37 (1946)

A study of characteristics of various types of arcs used as light sources.

B-3 KING, A. S., "Spectroscopic Phenomena of the High Current Arc," Astrophys. J. 62, 238-264 (1925)

Studied high current arc and found spectrum similar to that of E. W. P.

S-2 KLUGE, W. and HOCKER, K. H., "Ohmic Heating of Fully Ionized Plasmas," Proceedings of the Fourth International Conference on Ionization Phenomena in Gases, Vol. II, N. R. Nilsson (ed), North-Holland Pub. Co., Amsterdam (1960)

E-115 KORNEFF, T., BOHN, J. L. and NADIG, F. H., "Exploding Wire Phenomena at Reduced Pressures," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 104-117

Eb-7 LEOPOLD, H. S., "Effect of Energy Termination on the Initiation of PETN by Exploding Wires," NOLTR 65-56 (1965)

R-6 LOCHTE-HOLTGREVEN, W., "Production and Measurement of High Temperatures," Rep. Progr. Phys. 21, 312-383 (1958)

P-12 MALET, L. and ROSEN, B., "Etude spectrographique des molecules NiO et CoO," Bull. Soc. Roy Sc. Liege 14, 382-389 (1945)

N-8 MARTIN, E. A., "The Underwater Spark: An Example of Gaseous Conduction at about 10,000 Atmospheres," Univ. of Michigan 2048-12-F (July 1956)

B-4 MAURY, E., "Phénomènes consécutifs à un court-circuit provoqué par un fil fusible sur un réseau à 220 kilovolts," Rev. Gen. Elect. 54, 131-138 (1945) (Phenomena resulting when a short-circuit is produced on a 220 kv network by a fusible wire)

The author studies the question of whether isolated arc points are produced when a wire is connected to a discharge circuit, or whether an eventual arc results. Quantitative results in terms of wire size, capacity, and voltage are given. The inductance of the circuits used were in all cases quite large.

B-5 ROTHSTEIN, J., " The Arc Spot as a Steady-State Exploding Wire Phenomenon," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York, (1964) p. 115-123

In mercury-type arc spots, concentrated ionic bombardment of a small region is accompanied by intense emission of both electrons and an energetic vapor or plasma jet. It is proposed that differences between arc spot and E. W. P. are more in detail than fundamental.

S-7 TIMOFEEVA, G. G., "Pinch Effect and Breaking of the Arc in the Constriction," Zh. Techn. Fiz. 27, 2669-2671 (1957) (trans. in Soviet Physics-Tech. Phys. 2, 2480-2481 (1957)

E-201 TUCKER, T. J., "Dependent Resistivity of Exploding Wires," J. Appl. Phys. 30, 1841-1842 (1959)

Section B

R-13 VANYUKOV, M. P. and MAK, A. A., "High-Intensity Pulsed Light Sources," Uspekhi Fiz. Nauk. 66, 301-329 (1958) Trans. in Soviet Phys. — Uspekhi 66, 137-155 (1958)

CURRENT – Section C

E-8 ANDERSON, G. W. and NEILSON, F. W., "Use of the 'Action Integral' in Exploding Wire Studies," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 97-103

C-1 BELLASCHI, P. L., "Lightning Currents in Field and Laboratory," Elec. Eng. 54, 837-843 (1935)

Among other results, some data on the effects of lightning currents on conductors. A description of crushing (pinch effect) and "explosive effects."

K-3 BORODOVSKAYA, L. N. and LEBEDEV, S. V., "Dependence of the Electrical Conductivity and Electron Emission on the Energy of a Metal in the Process of its Heating by a Current of High Density," Zhur. Eksp. i teoret. Fiz. 28, 96-110 (1955) Soviet Phys. — JETP 1, 71-83 (1956)

K-4 BOROVIK, E. S., "Electrical Conductivity of Metals at High Current Densities," Soviet Phys. — Doklady 91, 771-774 (1953)

E-61 CHACE, W. G., MORGAN, R. L., and SAARI, K. R., "Conductivity During the 'Dwell-Time' of a Wire Explosion," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 59-72

X-12 CNARE, E. C., "Exploding Wire Detonation: An Approximate Method of Predicting Exploding Wire Detonator-Capacitor Discharge System Performance," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 185-192

C-2 HERING, C., "Revision of Some of the Electromagnetic Laws," J. Franklin Inst. 192, 599-622 (1921)

Discussion of magnetic pinch effect in liquid metals.

K-6 IGNATYEVA, L. A. and KALASHNIKOV, S. G., "Electric Resistance of Metals in the Case of Large, Pulsed Current Densities," Zhur. Eksp. i Teoret. Fiz. 22, 385-399 (1952)

C-3 MANINGER, R. C., "Radial Distribution of Current and Its Effect in an Exploding Wire," Exploding Wires Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 156-169

An analysis of short duration currents in a wire. Skin effect can cause time-dependent radial distribution of current in the wire. The effects of the current distribution on exploding wire phenomena are discussed.

Eb-24 TUCKER, T. J., "Exploding Wire Detonators: The Burst Current Criterion of Detonator Performance," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 175-184

ENERGY - Section D

E-5 ABRAMOVA, K. B., VALITSKII, V. P., VANDAKUROV, Yu V and PEREGOD, B. P., "Magnetohydrodynamical Instabilities in Electrical Explosion," Phys. Letters (Netherlands) 18, 286-288 (1965)

R-1 BEHRENS, W., "Temperature Bestimmung bei Elektrischen Draht Explosionen," Dis. Hannover 1935 Abs. in Physik Ber. 16, 1958 (1935) (Temperature Determination in Electrical Wire Explosions)

E-23 BENNETT, F. D., "Initial Heating Rates and Energy Inputs for Exploding Wires," Phys. of Fluids 7, 147-148 (1964)

E-29 BENNETT, F. D., "Energy Partition in Exploding Wire Phenomena," Phys. Fluids 1, 515-522 (1958)

E-28 BENNETT, F. D., "Energy Partition in the Exploding Wire Phenomenon," B.R.L. Rep. 1056 (Oct 1958)

K-3 BORODOVSKIA, L. N. and LEBEDEV, S. V., "Dependence of the Electrical Conductivity and Electron Emission on the Energy of a Metal in the Process of its Heating by a Current of High Density," Zhur. Eksp. i Teoret. Fiz. 28, 96-110 (1955) Soviet Phys. JETP 1, 71-83 (1956)

D-1 EARLY, H. C. and WALKER, R. C., "The Economics of Multi-million Watt-Second Inductive Energy Storage," Trans. Am. Inst. Elec. Engrs. Winter Conference Paper 56-333 (1956)

Discussion of economics of energy storage by condenser, coil, and battery. Describes University of Michigan inductance coil storage system.

E-91 FOURNET, M., "Phénomènes provoqués par des implosions de courant intenses dans des conducteurs résistants," Comptes Rendu 252, 2084-2086 (1961) (Phenomena produced by implosions of heavy current in resistive conductors)

E-92 FÜNFER, E., KEILHACKER, M., and LEHNER, G., "Zum Mechanismus von Drahtexplosionen," Z. angew. Physik 10, 157-162 (1959) (On the Mechanism of Wire Explosions)

D-2 GOOD, R. C., Jr., "Structural Response to Intense Electromagnetic Radiation," G. E. Space Science Lab. Report AFOSR-2483, First Annual Tech. Rep. (Feb 1962)

E. W. with 10^7 watts available produced "light" energy which was focused on small samples of materials, e. g. glass. Surface damage was recorded and studied. Equipment is described. A theory is developed which accounts for the crazing of glass.

D-3 KAPITZA, P., "A Method of Producing Strong Magnetic Fields," Proc. Roy. Soc. (London) 105, 691-710 (1924)

A discussion of the methods of storing energy for large pulsed currents. Although the author discusses magnets, the ideas are applicable to E. W. P.

E-117 KUL'GOVCHUK, V. M., "Development of Luminous Zones in Electrical Detonation of Thick Wires," Zh. Priklad. Mekh. i Teknich. Fiz. 4, 165-168 (1965)

E-131 LEBEDEV, S. V., "Phenomena in Tungsten Wires Preceding Their Disintegration Under the Effects of Heavy Current," Zhur. Eksp. i Teoret. Fiz. 27, 605-614 (1954)

Eb-11 LEOPOLD, H. S., "Effect of Wire Length on the Initiation of PETN by Exploding Wires," NOLTR 64-61 (1964)

Eb-9 LEOPOLD, H. S., "Effect of Wire Material on the Initiation of PETN by Exploding Wires," NOLTR 64-146 (1964)

Eb-8 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires," NOLTR 65-1 (1965)

E-133 LEVINE, P. H., TOLLESTRUP, A. V. and WEBB, F. H., Jr., "Electrical Conduction in Rapidly Exploded Wires," Proceedings of the Fifth International Conference on Ionization Phenomena in Gases, p. 2034-2053, H. Maecker (ed), North-Holland Pub. Co., Amsterdam (1962)

E-136 LUNDQUIST, S., "Some Observations on High-Current Channels in Air with Application to Lightning Discharge," Arkiv f. Fysik 31, 173-176 (1966)

E-140 MEDVED, D. B. and TURNBULL, W., "Microwave Absorption of Exploding Wire Plasmas," Bull. Am. Phys. Soc. 7, 441 (1962)

S-4 MEEKER, M. E., "Solid and Solid-Liquid Phases in Wires at High Current Densities," Sandia Tech. Memo SCTM 314-58 (51) (1958)

E-147 MULLANEY, G. J., BROWN, E. A., Jr., and AHLSTROM, H., "Exploding Wire Study," Boeing Sci. Res. Lab. Rev. 14, 20-22 (1965)

E-168 PEREGUD, B. P., and ABRAMOVA, K. B., "Experimental Study of Electrical Explosion," Dokl. Akad. Nauk SSSR 157, 837-840 (1964), Transl. in Soviet Physics-Doklady 9, 665-667 (1965)

E-192 STARR, W. L. and NAFF, J. T., "Acceleration of Metal Derived Plasmas," Lockheed Tech. Memo LMSD-288240 (Dec 1959)

E-196 THOMAS, R. L., and HEARST, J. R., "An Electronic Scheme for Measurement of Exploding Wire Energy," Lawrence Rad. Lab. (Livermore) UCRL-14170 (1965)

E-201 TUCKER, T. J., "Possible Explanation of the Current Density - Dependent Resistivity of Exploding Wires," J. Appl. Phys. 30, 1841-1842 (1959)

U-10 WUNSCH, D. C., SOAPES, T. D. and GUENTHER, A. H., "Acceleration of Thin Plates by Exploding Foil Techniques," A. F. Special Weapons Lab. Report AFSWC-TDR-61-75 (Jan 1962)

E-220 ZAREM, A. M., MARSHALL, F. R. and POOLE, F. L., "Transient Electrical Discharges: Disintegration of Small Wires," Phys. Rev. 72, 158 (1947)

EXPLODING WIRES – Section E

E-1 ANON, " Exploding Wires to Disrupt and Create," New Scientist 23, 381 (1964)

Very brief description of E. W. Conference No. 3.

U-1 ANON. "Metallic Vapor Plasma: Future Propellant.," Electronics 20-21 (Aug. 18, 1961)

E-2 ANON. "Statement on Electro-Optical Systems Work for Army," Missile Design and Development 7, (March 1960), Exploding Wires

A study of possible uses of E. W.'s.

Section E

E-3 ABRAMOVA, K. B., VALITSKII, V. P., VANDAKUROV, Yu. V., ZLATIN, N. A., and PEREGUD, B. P., "Magnetohydrodynamic Instabilities During Electrical Explosion," Doklady Akad. Nauk. SSSR 167, 778-781 (1966), Trans. in Soviet Physics - Doklady 11, 301-304 (1966)

In rather slow explosions both "screw" and "pinch" instabilities were observed by X-rays and the results correlated with theory. The agreement was good for "pinch", but rather poor for the screw type. The conclusion is that the explosion is due to breaks caused by instabilities.

E-4 ABRAMOVA, K. B., VALITSKII, V. P., VANDAKUROV, Yu. V., ZLATIN, N. A., and PEREGUD, B. P., "Magnetohydrodynamic Instabilities in Electrical Explosion," Private communication (1965)

The authors study rather slow explosion (15-77μs first pulse) by X-ray shadowgraphs and find screw and sausage type instabilities. These are related to hydrodynamic formulas and satisfactory agreement found.

E-5 ABRAMOVA, K. B., VALITSKII, V. P., VANDAKUROV, Yu. V. and PEREGUD, B. P., "Magnetohydrodynamical Instabilities in Electrical Explosion," Phys. Letters (Netherlands) 18, 286-288 (1965)

Very slow (first pulse 15 to 77μs) explosions were studied by X-rays. A threshold energy is defined below which an explosion does not occur. When $E_{in} < E_{thr}$ a screw instability results. If $E_{in} > E_{thr}$ a sausage instability develops. If $E_{in} > E_{thr}$ but very near equal, both occur simultaneously.

E-6 ALLEN, W. A., HENDRICKS, C. H., MAYFIELD, E. B., and MILLER, F. M., "Electronic Shutter Photographs of Exploding Bridge Wires," Rev.Sci.Instr. 24, 1068-1069 (1953)

Photographs with Rapatronic shutter camera. The authors also studied electrical behavior by placing wire in arm of 3 cm microwave bridge and noting the unbalance. When the wire is exploded in an electrostatic field the rate of unbalance is shortened. Postulate space charge.

N-1 ABRAMSON, I. S., and MARSHAK, I. S., "A High-Power Electric Spark in Air at Atmospheric Pressure," Zh. Techn. Fiz. 12, 632-639 (1942)

E-7 ALLISON, S. K. and HARKINS, W. D., "The Absence of Helium from Gases Left After the Passage of Electric Discharges," J. Am. Chem. Soc. 46, 814-824 (1926)

Repeated the Wendt and Irion experiment looking for helium from discharges. Used principally discharge between metallic points. Also tried a few E. W. P. experiments.

E-8 ANDERSON, G. W. and NEILSON, F. W., "Use of the 'Action Integral' in Exploding Wire Studies," Exploding Wires, Vol. 1, Chace and Moore (eds), Plenum Press, New York (1959) p. 97-103

Defines action integral as $I(t) = i^2 dt$ and shows that it is often more useful in E. W. study than is energy integral $U = i^2 r dt$.

E-9 ANDERSON, J. A., "Electrically Exploded Wires," International Critical Tables, Vol. 5, p. 434 (1929)

Bibliography and brief description of phenomenon. Development of spectra with time is discussed.

E-10 ANDERSON, J. A., "The Spectral Distribution and Opacity of Wire Explosion Vapors," Proc. Natl. Acad. Sci. U.S. 8, 231-232 (1922)

The author measured the spectral energy from the infrared to the ultraviolet. Found that the continuous spectrum is the same for all metals tested. Also tried to pass spectrum from a spark through an exploding wire plasma. Found plasma opaque, 4 cm being perfectly opaque.

E-11 ANDERSON, J. A., "Spectra of Explosions," Proc. Natl. Acad. Sci. U.S. 6, 42-43 (1920)

A study of the spectrum of exploding iron wires.

E-12 ANDERSON, J. A., "The Spectrum of Electrically Exploded Wires" Astrophys. J. 51, 37-48 (1920)

The author points out that E. W. P. produces a more nearly complete absorption spectrum than any other laboratory source. The continuous background extends into the extreme ultraviolet. Intrinsic brightness is greater than the sun. Believes continuous spectra come from gases at relatively low pressure. Plates of typical spectra are given.

E-13 ANDERSON, J. A. and SMITH, S., "General Characteristics of Electrically Exploded Wires," Astrophys. J. 64, 295-314 (1926)

The authors discuss mainly techniques for studying E. W. P. They discuss and analyze (1) the storage condenser and circuit, (2) rotating mirror camera and spectrograph, (3) other fast photographic methods (4) methods of estimating temperature, (5) double gap method for studying early stages of the explosion. A few results are given and discussed.

X-2 ANDREEV, S. I. and VANYUKOV, M. P., "Use of Electrical Explosion of Wires to Produce Ultra-Short Light Flashes," Zh. Techn. Fiz. 34, 1871-1872 (1964) Trans. in Soviet Physics-Tech. Phys. 9, 1443-1444 (1965)

Section E

X-3 ANDREEV, S. I. and VANYUKOV, M. P., "Methods of Shortening Light Flash Duration and Increasing Intensity." VI Internat. Congress on High-Speed Photog. The Hague (1963), p. 166-172

E-14 ARNOLD, H., and CONN, W. M., "About Distances in the Characteristic Pattern of Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 77-86

A statistical study of the striations formed in the vapor deposits from E.W.'s.

W-1 AYCOBERRY, C., BRIN, A., DELOBEAU, F., and VEYRIE, P., "Striction de Plasmas Metalliques Obtenus Par Explosions de Fils," V Internat. Conf. on Ionization Phenom. in Gases, Munich (1961), Vol. I, p. 1052-1059 (Pinch in Metallic Plasmas Obtained from Wire Explosions)

M-1 BAIRD, K. M., "Shock Waves in Glass," Nature 160, 24-25 (1947)

X-4 BAKER, L., Jr., and WARCHAL, R. L., "Studies of Metal-Water Reactions by the Exploding Wire Technique," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 207-223

E-15 BAKER, L., WARCHAL, R. L., VOGEL, R. C., and KILPATRICK, M., "Studies of Metal-Water Reactions at High Temperatures - I. The condenser discharge experiment. Preliminary results with zirconium," Argonne Natl. Lab. ANL-6257 (May 1961)

Condenser discharge i.e., exploding wire methods of producing heated metals in water were employed to study Zr-water reaction. Methods of measuring total energy delivered, and temperature are described. Results in terms of % reaction and H_2 evolved are given for temps from 1000° to 4000°.

E-16 BALK, O., "Zahlrohrmessungen an Drahtexplosionen," Naturwissenschaften 43, 511 (1956) (Counter Tube Measurements on Exploded Wires)

Repeated experiment of Conn (E-72). Negative Results.

E-17 BARKOW, A. G., KARIORIS, F. G., and STOFFELS, J. J., "X-ray Diffraction Analysis of Aerosols from Exploding Wires," in Advances in X-ray Analysis, VI, Plenum Press, New York, p. 210-222 (1963)

An x-ray diffraction study of the composition of aerosols produced by E.W. Particles are crystalline from 15 metals exploded in air. Particles are metals from wire exploded in argon and from noble metals exploded in air. Base metals in air form principally oxides. Nitrides not observed. Composition is varied (e.g., ratio of CuO, Cu_2O, and Cu from Cu wire) by varying the voltage.

E-18 BARTELS, H., BORTFELDT, J., BERG, K. H., "Über den Zündungsprozess bei Drahtexplosionen," Proc. of the Fifth International Conference on Ionization Phenomena in Gases Vol. I, H. Maecker (ed), North Holland Pub. Co., Amsterdam (1962), p. 1048-1051 (On the Ignition Process in Wire Explosions)

High speed photos and spectrograms of E.W.'s. At 100 mm and 200 mm in rare gas atmospheres, the gas surrounding the wire breaks down first. Only under special circumstances does the wire also explode and when it does the early spectrum is of the rare gas, not of Cu.

E-19 BARTELS, H. and BORTFELDT, J., "Some Experimental Results of Exploding Wire Research and Their Applications in Plasma Physics," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 9-21.

The ignition of the gas discharge in exploding wires in argon with voltage exceeding sparking potential always begins at both ends of the wire in a manner clearly dependent on the polarity. The possible mechanism is discussed. In E.W. experiments in air, the relative spectral distribution of the absolutely measured intensities and the optical thicknesses could be determined with a degree of accuracy sufficient for estimation of the temperatures. It can be shown that the maximum intensities are caused by shock waves reflected at the axis of discharge. The role of the shock waves heating the metal vapor is discussed briefly. As an example of E.W. application in plasma physics, photographs and intensity measurements of exploding wires as preformed plasma for high-energy Z-pinch at atmospheric pressure are discussed.

L-1 BARTELS, H. and EISELT, B., "Über ein einfaches Verfahren zur kinematographischen Aufnahme schnell verlaufender Vorgänge," Optik 6, 56-58 (1950) (A Simple Method for Cinematographic Photograph of Rapidly Occurring Processes)

W-2 BARTELS, H., GANSAUGE, P., and KUHLMEI. H., "Magnetische Kompression in Gasen Höherer Dichte," V Internat. Conf. on Ionization Phenom. in Gases, Munich (1961), p. 2032-2033 (Magnetic Compression in Gases at High Densities)

E-20 BAXTER, H. W., Electric Fuses, Edward Arnold, London (1950)

Theoretical as well as practical discussion of slow speed fusion of wires. Experimental results are given but very few original references.

R-1 BEHRENS, W., "Temperatur Bestimmung bei Elektrischen Draht Explosionen," Dis. Hannover, Abs. in Physik Ber. 16, 1958 (1935) (Temperature Determination in Electrical Wire Explosions)

Q-3 BELLASCHI, P. L., "Laboratory Lightning - The Microsecond Switch," Elec. J. 33, 273-275 (1936)

E-21 BENNETT, F. D., "Nonlinear Equations for Circuits Containing Exploding Wires," Phys. of Fluids 9, 471-477 (1966)

A set of nonlinear differential equations applicable to damped oscillatory circuits with exploding wires is developed. From these an exact first integral, or conservation law, is obtained. The range of validity is examined. Limitations are established and an examination of experimental conditions to extend these limits is made. Calculations of time-to-melt are made and compared with experimental values. Major regimes of circuit behavior are delineated and discussed.

E-22 BENNETT, F. D., "High Temperature Cores in Exploding Wires," Phys. of Fluids 8, 1106-1108 (1965)

The author postulates the resistance rise is due to inward travelling vaporization wave which changes wire to nonconducting gas. Wire is heated for longer times in center. Temps. of 10^7°K are theoretically possible. This is actually limited by breakdown of gas around the wire.

E-23 BENNETT, F. D., "Initial Heating Rates and Energy Inputs for Exploding Wires," Phys. of Fluids 7, 147-148 (1964)

Formulas are given for calculating resistance, mass, power input, rate of temperature rise, and energy based on readily available constants of the material diameter, length, conductivity, density, specific heat. The formulas are valid from switch-on to the beginning of expansion. A table of values of some constants involved is given for metals commonly used in E.W. experiments.

E-24 BENNETT, F. D., "Exploding Wires," Scientific American 206, p. 103 (May 1962)

More or less popular exposition of E.W. behavior and the BRL system of study-streak cameras and interferometers. Shock wave behavior is stressed.

E-25 BENNETT, F. D., "Shock Producing Mechanisms for Exploding Wires," BRL Report 1161 (Feb. 1962)

Single fringe interferograms are presented of 4-mil Cu wires exploded at 20 kv into argon at ambient pressures of 1/8, 1/16 and 1/32 atm. Features discernible include a compressive head shock wave, arc plasma, a weak plasma wave and the expanding metal wire. On the basis of certain plausible assumptions it is seen that the arc plasma has a temperature of about 2.5 ev; but its leading edge, a region not in thermal equilibrium, has electron temperatures $\sim 10^2$ ev and is the boundary of an electron driven shock wave.

E-26 BENNETT, F. D., "Shock-Producing Mechanisms for Exploding Wires," Phys. of Fluids 5, 891-898 (1962)

See Bennett, BRL Report 1161. (E-25).

H-2 BENNETT, F. D., "Transient Skin Effects in Exploding Wire Circuits," BRL Report 1137 (August 1961)

E-27 BENNETT, F. D., "Flow Fields Produced by Exploding Wires," BRL Report 1075 (May 1959)

Further study of shock wave problems, using linear streak back-lighting with rotating mirror. Concludes, among other things that an E. W. acts as a transducer between electrical and fluid mechanical energy and hence that its apparent resistance in the circuit depends on density of surrounding medium. An attempt is made to relate flow to variable energy similarity flows. Shows experimentally that actual shock trajectories do not differ much for different ambient densities.

M-2 BENNETT, F. D., "Cylindrical Shock Waves from Exploded Wires of Hydrogen-Charged Palladium," BRL Report 1063 (January 1959)

M-3 BENNETT, F. D., "Cylindrical Shock Waves from Exploded Wires of Hydrogen-Charged Palladium," Phys. Fluids 2, 470-471 (1959)

M-4 BENNETT, F. D., "Flow Fields Produced by Exploding Wires," Exploding Wires Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 211-266

M-6 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Bull. Am. Phys. Soc. 3, 292 (1958)

E-28 BENNETT, F. D., "Energy Partition in the Exploding Wire Phenomenon," BRL Report 1056 (Oct 1958)

A study by streak camera and oscillograph of relation between shock wave energy and electrical and heat energy in E. W. P. Wire diameter (3 to 8 mils) is the principle parameter. Calculation of power dissipated in an E. W. circuit in appendix.

E-29 BENNETT, F. D., "Energy Partition in Exploding Wire Phenomena," Phys. Fluids 1, 515-522 (1958)

(See E-28)

Section E

E-30 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Phys. Fluids 1, 347-352 (1958)

(See E-31)

E-31 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," BRL Report 1035 (1958)

Rotating mirror camera modified with a stationary plane mirror placed to give coincident second reflection. This backlights non-luminous shocks and makes them visible. Also streak photographs. Shocks up to Mach 9 were produced by E. W. P.

E-32 BENNETT, F. D., BURDEN, H. S., and SHEAR, D. D., "Correlated Electrical and Optical Measurements of Exploding Wires," BRL Report 1133 (June 1961)

By relating current, voltage, light, and streak photographs the authors develop a comprehensive picture of wire explosions, especially those with wires matched to the internal electrical circuit.

E-33 BENNETT, F. D., KAHL, G. D., WEDEMEYER, E. H., "Resistance Changes Caused by Vaporization Waves in Exploding Wires," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 65-88.

The marked increase in electrical resistance occurring at temperatures above melting can be explained by assuming a vaporization-expansion wave proceeding radially inward from the wire surface. This wave reduces the conducting cross section of the wire, thereby increasing the resistance. For wires well matched to the circuit the resistance rise occurs when the condenser voltage is practically zero and can be neglected; and for thin wires that explode rapidly on the linear portion of the current curve, condenser voltage can be taken as constant. Under these assumptions the circuit equation can be integrated and explicit expressions obtained for current, power, and deposited energy. A theoretical fluid dynamical model of an expansion wave involving a phase change from liquid to wet vapor is investigated; this analysis shows the expected velocity of small amplitude waves to be very close to the experimental value cited above. The theory predicts both the onset of the wave and the wave speed as a function of deposited energy up to the critical temperature. Beyond critical temperature, where the liquid to vapor expansion does not apply, the wave speed should be only a function of deposited specific energy.

H-3 BENNETT, F. D., and MARVIN, J. W., "Current Measurement and Transient Skin Effects in Exploding Wire Circuits," Rev. Sci. Instr. 33, 1218-1226 (1962)

M-5 BENNETT, F. D., and SHEAR, D. D., "Shock Waves from Exploding Wires at Low Ambient Densities," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 181-194

E-34 BENNETT, F. D. and SHEAR, D. D., "Shock Waves from Exploding Wires at Low Ambient Densities," BRL Report 1152 (Oct 1961)

Modification of the method of streak interferometry is described. A system of very narrow band filters replaces the monochrometer. Using this technique to study the explosion of 4 mil Cu wires at reduced pressures shows that at 1/16 atm the shock comes not only from the unconfined expansion of metal vapor but in the early stages from expansion of the plasma of the peripheral arc. Electron density in the annular region reaches as high as 10^{18}/cc.

E-35 BENNETT, F. D. and SHEAR, D. D., "Visualization of Cylindrical Shock Waves," Phys. Fluids 2, 338-339 (1959)

(See A-2)

A-2 BENNETT, F. D., and SHEAR, D. D., "Visualization of Cylindrical Shock Waves," BRL Memo Report 1199 (March 1959)

E-36 BETHGE, O., "Mechanische Verformungen durch elektrische Entladungen," Ann. Physik 8, 475-499 (1931) (Mechanical Distortions due to Electrical Discharges)

An exhaustive quantitative discussion of bends formed in wires by surges of current just below the fusion point.

E-37 BEUCHELT, R. and BÖHM, E., "Über eine Temperatur - und Druckmessung im Plasma von Drahtexplosionen," Naturwissenschaften 44, 507 (1957) (Temperature and Pressure Measurement in the Plasma from Exploding Wires)

A discussion of temperature determination from line width measurement. A temperature of 63,000 °K ± 12% is found in discharge of a wire 0.03 mm dia. The pressure was 135 atm ± 10%.

E-38 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D. Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S.N. Res. Lab. Prog. Rep. 1 Feb - 1 May 1962

Calculations of time of X-ray pulse from imploding tube show pulse length of $\sim 8 \times 10^{-9}$ sec at half power. Attempts are being made to increase pulse length. Time resolved spectroscopy used to approximate temp. gave value of 25,000°K 1μs after start. Also gave ion count of N^+ $2.58 \times 10^{15}/cm^3$ and N^{++} $8.82 \times 10^{16}/cm^3$ and at $t = 10^{-6}$, 1.8×10^{17} electrons/cm^3.

E-39 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S.N. Res. Lab. Prog. Rep. (1 Nov 1961 to 1 Feb 1962)

> Calculations supporting x-ray production from bremsstrahlung. Kinetic electron temperature is calculated to be 2.6 KeV from photo studies. Power measurements were attempted. A voltage measuring system was devised and tested. Studies were made of a mylar-oil capacitor. Details of the voltage divider are given.

T-1 BEY, P. P., FAUST, W. R., FULPER, R., Jr., HARRINGTON, F. D., LEAVITT, G. E., SHIPMAN, J. D., and VITKOVITSKY, I. M., "Exploding Wire Studies," U. S. N. Res. Lab. Prog. Rep. (1 Aug to 1 Nov 1961)

Q-2 BINDER, K., "Die Entwiklung von Schaltfunkenstrecken für ein schnelle 15 kJ-Kondensatorbatterie für Drahtexplosionen bei 100 kV," (Development of a Sparkgap Switch for a Fast 15 kJ Capacitor Bank for Wire Explosions at 100 kV), in Forschungsbericht K66-27, Bundesminesterium für wissenschaftliche Forschung (July 1966) (Research Report K66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

N-2 BLOXSOM, D. E., "Production of High Temperature, Moderate Pressure Gases by Means of Electric Spark Discharges," Arnold Eng. Dev. Cent. AEDC-TN-56-17 (1956)

P-2 BODSON, E., and DEHALU, F., "Neuvelles récherches sur les bandes de l'oxyde d'aluminum," Bull. Acad. Belg. 23, 408 (1937) (New research on the bands of aluminum oxide)

X-6 BOHN, J. L., NADIG, F. H. and SIMMONS, W. F., "Acceleration of small Particles by Means of Exploding Wires," in Exploding Wires Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 339-351.

K-2 BONDARENKO, V. V., KVARTSKHAVA, I. F., PLIUTTO, A. A., and CHERNOV, A. A., "Resistance of Metals at High Current Densities," Zhur. Eksp. i Teoret. Fiz. 28, 191-198 (1955), Soviet Phys. JETP 1, 221-226 (1955)

E-40 BONPAS, M., ERTAUD, A., LEGRAND, J. P., and MEUNIER, R., "Expériences Préliminaries sur les Radioactivities Consécutives a l'Explosion de Fils Contenant Deutérium," J. Phys. Radium 18, 585-589 (1957) (Preliminary Experiments on Radioactivity Resulting from the Explosion of Wires Containing Deuterium)

> The author tried to repeat Conn's radioactivity experiment (E-72) Results were negative. Used wires containing deuterium and tritium with positive results here. Elaborate precautions to overcome high background to sample ratio.

E-41 BRAUN, F., "Der Mechanismus der elektrischen Zerstaubung; Schmelzen von Kohlenstoff; Zerlegung von Metallegierungen," Ann. Physik 17, 359-363 (1905) (The Mechanism of E··ctrical Sputtering; Fusion of Carbon; Segregation of Alloys

The author exploded wires and condensed the resulting vapor on glass plates. Studied effects produced. Concludes metal is deposited, not oxides.

E-42 BRISCOE, H. V. A., ROBINSON, P. L. and STEPHENSON, G. E., "The Electrical Explosion of Tungsten Wires," J. Chem. Soc. (London) 127, 240-247 (1925)

The authors repeated the Wendt and Irion experiment exploding tungsten wires in vacuum. No evidence of the formation of helium.

E-43 BUNTZEN, R. R., "Hydra Program - The NRDL Low-Yield Underwater explosion Tank and Associated Instrumentation," Naval Radiological Defense Lab, USNRDL TR-623 (Feb 1963)

An apparatus for studying simulated underwater nuclear explosions on laboratory scale using exploding wires is described. The energy storage system, trigger device and discharge circuit are shown, as well as the instrumentation.

X-7 BUNTZEN, R. R., "The Use of Exploding Wires in the Study of Small-Scale Underwater Explosions," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 195-205.

E-44 CARNE, E. B., "A Mechanism for the Fuse Pre-Arcing Period," Trans. Am. Inst. Elec. Engrs., Pt III 72, 593-599 (1953)

The space-time development of fusing is calculated from classical heat conduction, pinch effect, heat loss, Clausius-Chaperyon, etc., equations. It is calculated that for rapidly heated wires (Cu, Ag) melting should occur at the center.

P-3 CASE, Roger S., Jr., "Time Resolved Spectroscopy of Exploding Wires," Thesis, AFIT GSP/PH/66-2 (1966)

F-1 CASSIDY, E. C. and ABRAMOWITZ, S., "Studies of Some Exploding Wire Light Sources," J. Soc. Mot. Picture and T. V. Engrs. 75, 734-737 (1966)

E-45 CASSIDY, E. C. and ABRAMOWITZ, S., "Watching a Wire Explode," New Scientist 31, 136 (1966)

Description of the spectroscopic study of Al and Ti wires exploded in A_1, N_2, H_2. Ti gives very intense u. v. and is used to study absorption in AlO and AlH bands. (A news item).

Section E

E-46 CHACE, W. G., "Use of X rays in Exploding Wire Studies," Bull. Am. Phys. Soc. 10, 166 (1965)

Paper describing preliminary studies of wires and foils by X rays. Discusses plasma sheath and shape changes principally.

E-47 CHACE, W G., Usp. Fis. Nauk 85, 381-386 (1965)

A translation of Physics Today 17, 19-24 (Aug 1964).

E-48 CHACE, W. G., "A Survey of Exploding Wire Progress," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 1-7

Review (1773 to 1963) of trends and major developments of theory and uses of E. W.

E-49 CHACE, W. G., "Exploding Wires," Physics Today 17, 19-24 (Aug 1964)

A survey of exploding wire history and the modern uses. A short review of the 1964 E. W. conference is included.

E-50 CHACE, W. G., "Exploding Wires and Their Uses," New Scientist (London) 18, 386-388 (1963)

A popular article on tl ory and uses of E. W.'s.

E-51 CHACE, W. G., "Introduction," in Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 1-4

A general discussion of E. W. changes since publication of Volume I. Includes particularly a discussion of classification, quantitative data, communication, and exploding foils.

E-52 CHACE, W. G., "Observations in High Density Plasmas Produced by Exploding Wires," Proc. of the Fourth International Conference on Ionization Phenomena in Gases," Vol. II, pp. IVE 1191 - IVE 1195, N. R. Nilsson (ed), North-Holland Pub. Co., Amsterdam (1960)

Measurements of current during dwell showed density of 10^5 A/cm^2. High speed photographs and flash x-rays indicate mechanism of vaporization from highly superheated liquid. Density of resulting vapor is order of 10^2 atoms/cm^3 and its conductivity is intermediate between a "normal" gas and a plasma. Restrike results from onset of avalanching.

E-53 CHACE, W. G., "A Brief Survey of Exploding Wire Research," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York, p. 7-13 (1959)

A very brief historical sketch, the author's view of the mechanism of the explosion, and a short statement about some of the uses to which E. W.'s have been put.

E-54 CHACE, W. G., "The Liquid Behavior of Exploding Wires," Phys. Fluids 2, 230-235 (1959)

A theory of explosion due to superheating, supported by high speed photographs. The role of unduloids in striation formation is also disputed.

E-55 CHACE, W. G., "A Bibliography of the Electrically Exploded Wire Phenomenon," Second Edition, AFCRC-TN-58-457 (Nov 1958), ASTIA Document No. AD-152640

Second edition extending the literature of E. W. P. from 1774 to July 1958.

E-56 CHACE, W. G., "Details of Behavior of a Wire During Electrical Explosions," Paper delivered before Tenth Annual Gaseous Electronics Conference, M. I. T. (Oct 1957)

Presentation of superheat theory coupled with the unduloid theory. Dwell related to vaporization. Experimental proof presented. Equation for dwell time (empirical) offered.

E-57 CHACE, W. G., "A Bibliography of the Electrically Exploded Wire Phenomenon," AFCRC-GRD-TM-57-5 (Nov. 1956)

Briefly annotated bibliography of E. W. P. from 1815 through 1955.

A-7 CHACE, W. G. and CULLINGTON, E. H., "Instrumentation for Studies of the Exploding Wire Phenomenon," Instr. Geophys. Res. No. 7, AFCRC-TR-57-235 (1957)

J-1 CHACE, W. G., and FISH, C. V., "Exploding Wire Blast Shutter," Appl. Optics 2, 441-443 (1963)

E-58 CHACE, W. G. and LEVINE, M. A., "Classification of Wire Explosions," J. Appl. Phys. 31, 1298 (1960)

Four classes proposed in each of which phenomena are claimed to be comparable, while not always so between classes.

Classes

1. Melting $\frac{1}{2} C V_o^2 < W_v + \int I^2 R_o \, dt$
2. Slow $t_v > \Psi$
3. Fast $t_v < \Psi$
4. Ablative $t_v < \tau$

t_v = time to vaporize; Ψ = time constant of instabilities; τ = electrothermal time constant.

E-59 CHACE, W. G., and LEVINE, M. A., "Relations of Conductor Configuration to Vaporization in Exploding Wires," VI Internat. Conf. on Ionization Phenom. in Gases, Paris, Vol. II (1963) p. 621-625

The manner in which the explosive phase change occurs in a wire explosion was investigated experimentally. Should this change start at the surface and proceed toward the center, then surface to center distance should be a factor controlling rate and manner of explosion. Wire systems were exploded in which only surface to center distance was allowed to vary.

It was found that total time, maximum current, and rate of vaporization as measured by di/dt were all independent of surface to center distance. Thus it is postulated that the explosion occurs "simultaneously" throughout the wire.

E-60 CHACE, W. G., and MOORE, H. K. (eds), Exploding Wires, Vol. II, Plenum Press, New York (1962)

Proceedings of the Second Conference on the Exploding Wire Phenomenon, held in Boston, November 1961.

E-61 CHACE, W. G., MORGAN, R. L., and SAARI, K. R., "Conductivity During the 'Dwell-Time' of a Wire Explosion," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 59-72

Current was measured during dwell and found to be not zero but from 500 to 2000 amps for 10 cm wires of various diameter (0. 13 to 1 mm). Study of the current voltage relations during the period leads to theory that current is conducted by thermoions.

H-4 CHASE, N., HANKIN, N., and WEBB, F. H., Jr., "Instrumentation for Exploding Wire Research," Electronics, 43-45 (July 1960)

X-9 CHURCH, C. H., HAUN, R. D., Jr., OSIAL, T. A. and SOMERS, E. V., "Optical Pumping of Lasers Using Exploding Wires," Appl. Optics 2, 451-452 (1963)

X-10 CHURCH, C. H., HAUN, R. D., Jr., OSIAL, T. A., and SOMERS, E. V., "Optical Pumping of Lasers Using Exploding Wires," Westinghouse Research Lab., Sci. Paper 62-112-259-P1 (July 1962)

E-62 CLARK, G. L., HICKEY, J. J., KINGSLEY, R. J., and WUERKER, R. F., "Exploding-Wire-Driven Shock Waves," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York p. 175-180 (1962)

The explosion of fine silver wires by the fast discharge of a low-inductance capacitor has been photographed with an image-converter camera operated as a streak camera. All of the previously observed shock waves and contact surfaces have been clearly recorded. In addition, the large effective aperture of the camera, and its 50:1 light gain, has allowed the initial shock wave in air at atmospheric pressure

to be photographed by its own luminosity. Photographs of both radially and circumferentially propagating shock waves, depending upon dwell duration, have been recorded during the second conduction phase of the discharges.

X-11 CLINGMAN, D. L., GUBBINS, D. G., and ROSEBROCK, T. L., "The Influence of Electrode Geometry on Rail Accelerator Performance," Gen. Motors, Allison Div., Eng. Dept., Rept. No. 3163 (Jan 1963)

X-12 CNARE, E. C., "Exploding Wire Detonation: An Approximate Method of Predicting Exploding Wire Detonator-Capacitor Discharge System Performance," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 185-192

E-63 CNARE, E. C., "Electrically Imploded-Exploded Aluminum Tube," J. Appl. Phys. 32, 1275-1278 (1961)

Al tubes 19.0 cm (7 $\frac{1}{2}$")long, 0.476 cm dia. and 0.01 cm wall were exploded with 141 Kj at 20 kV. Observations — X-rays, I(t), and framing camera. The tube collapses, then melts, then explodes like a wire. For 3.7μsec no tube wall motion because pinch has not yet built up. Up to 10.5 μsec it seems that the tube collapses still as a solid. E.W. action takes place after 15μsec. Graphs and photos are shown.

A-8 CNARE, E. C., "An Exploding Wire as a Fuse for the LASL Capacitor Bank — Zeus," Sandia Corp. SC-4324 (TR), TID-4500 (14th Ed) (1959)

E-64 CNARE, E. C. and NEILSON, F. W., "Large Exploding Wires — Correlation to Small Wires and Pause Time versus Length Dependency," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 83-96

Large (up to 62 mil and up to 18 in. long) wires of Cu, and Fe were exploded with 49.5 Kj. The results were correlated with small wires. Relation between length and dwell time is established as well as the effects of confinement on the length of dwell.

E-65 COFFMAN, M. L., "The First Picosecond in an Exploding Wire," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 89-102

An exploding wire is regarded microscopically in detail for a picosecond to establish some concepts of a model. A resonant condition is assumed to develop within the wire, which expands at selective points. Increases in resistance temporarily, emits electrons by a thermionic process, becoming positively charged as a result, and finally explodes due to excessive Coulomb and thermal pressure. A technique is given for finding the separation distances of the resulting striations and a partial justification for the frequency with which the measured striation distances appear.

P-5 COHEUR, F. and ROSEN, B., "Le spectre des bandes de l'oxyde d'aluminum," Bull. Soc. Roy. Sc. Liege 10, 405-413 (1941) (The band spectrum of aluminum oxide)

X-13 CONN, W. M., "Use of the Exploding Wire Phenomenon for Research and Development Work in Glass Systems," Central Glass and Ceramic Research Inst. Bull. 11, 100-105 (1964)

E-66 CONN, W. M., "Über Drahtexplosionen mit unterbrochenem Draht," Z. Naturforsch, 13a, 355-356 (1958) (Wire explosions with interrupted Wires)

> The author describes E. W. P. where the wire is not continuous electrically, but comes near a vertical plate. The wire frequently breaks into sections, some of which weld themselves to the plate. It is claimed that the length of these sections is that of a secondary unduloid.

E-67 CONN, W. M., "Fenstermethode zur Beobachtung innerhalb von Metalldämpfen die bei kurzzeitigen Vorgängen auftreten. Beispiel: Drahtexplosionen," Naturwissenschaften 45, 6-7 (1958) (Window Methods for Observation within the Metal Vapors Produced in Short Time Events: Example: Exploding Wires)

> Wires were exploded close to a transparent plastic-like Mylar and high speed photographs taken.

E-68 CONN, W. M., "Observation of Phenomena Inside the Vapor Cylinder Formed During Explosion of a Metallic Wire," Bull. Am. Phys. Soc. 2, 376 (1957)

> Investigation of the physical shape of an E. W. during explosion by deposits of vapor on glass slides and by a nylon "window" to observe the interior of the vapor cloud.

E-69 CONN, W. M., "Studies of the Mechanism of Electrically Exploded Wires," Naturwissenschaften 42, 65-66 (1955)

> States theory resulting from work discussed in reference E-70 (In English).

E-70 CONN, W. M., "Studien zum Mechanismus von elektrischen Drahtexplosionen (Metallnieder schläge und Stosswellen)," Z. angew. Physik 7, 539-554 (1955) (Studies of the Mechanism of Electrical Wire Explosions)

> Very comprehensive article including an excellent bibliography. The author discusses experimental work leading to his theory of E. W. P. The theory postulates shock phenomena as the cause of reignition.

E-71 CONN, W. M., "Metallic Deposits and Shock Waves Due to Electrically Exploded Wires," Phys. Rev. 98, 1551 (1955)

> Abstract of a meeting paper describing results of metal deposits on glass and a theory of E. W. P. resulting from this work. This theory is fully discussed in reference E-70.

E-72 CONN, W. M., "A New Effect Observed in Connection with Electrically 'Exploded' Wires," Nature 169, 150 (1952)

> Report of ionizing radiation following explosion of copper wire. Measurement of total light energy.

E-73 CONN, W. M., "The Use of 'Exploding Wires' as a Light Source of Very High Intensity and Short Duration," J. Opt. Soc. Am. 41, 445-449 (1951)

> Investigated E. W. P. as a light source. Found copper best for photographic work and silver best for visual.

E-74 CONN, W. M., "A Coating Method Based on the Use of Electrically Exploded Wires," Phys. Rev. 79, 213 (1950)

> Discusses uses of E. W. P. for metallic coating.

E-75 CONN, W. M., "Note on the Polarization of Light Emitted by Electrically Exploded Wires," Phys. Rev. 58, 50-51 (1940)

> Studied polarization to determine source of continuous spectrum. Light reflected or scattered should be polarized. Found no polarization, hence continuous spectrum not due to this cause.

R-3 CONN, W. M. and DEEG, E. W., "Use of the Solar Furnace as an Intermediate Imaging Source for Attaining Extreme Temperatures for a Short Time," Bull. Am. Phys. Soc. 3, 375 (1958)

E-76 DAVID, E., "Exploding Wires, Calculation of Heating," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959) p. 271-279

> In a wire explosion, only that energy added in the short interval after the wire has exceeded temperature of vaporization but before it begins to expand produces high temperatures. Formulas are developed for calculating wire resistance producing maximum temperature. Terms are converted to dimensionless form and graphs are given showing behavior of these terms.

E-77 DAVID, E., "Physikalische Vorgänge bei elektrischen Drahtexplosionen," Z. Physik 150, 162-171 (1958)(Physical Processes in Electrical Wire Explosions)

Calculations of behavior at various stages of development, using data from Müller (E-148).

E-78 DAY, P. B., "The Radiant Intensity of Electrically Exploded Wires," J. Opt. Soc. Am. 43, 817 (1953)

A Method of photographic photometry is described from which spectral energy composition curves, and brightness temperatures of exploding wires may be obtained.

E-79 DÉCHÈNE, R., "Étude des Spectres de Fils Explosés," J. Phys. Radium 7, 59-64 (1926) (Study of the Spectra of Exploded Wires)

Investigation of spectra of several metals, particularly with respect to reversals. Uses reversal of lines in E. W. P. as a method of classifying spectral lines.

E-80 DERIBAS, A. A., and POKHOZHAEV, S. I., "The Problem of an Explosion on the Surface of a Liquid," Dokl. Akad. Nauk. SSSR 144, 524-526 (1962), Translated in Soviet Phys - Doklady 7, 383-384 (1962)

The authors used a 0. 1 mm wire to produce the explosion. They proved that impulse J_0 was the important parameter in their approximation.

E-81 DOLMATOV, K. I., TAZITDINOV, A. N. and TIMOKHINA, Yu. I., "Interruption of the Current Flow upon Electrical Explosion of Fine Wires in Air," IgvestiyaAkad. Nauk Uz SSR, Seriya Fiziko - matematicheskikh nauk No. 5, 86-88 (1966)

A study of dwell of W, Mo, Ta, and Fe wires. The usual relations are established for effects of length, dia, and voltage on dwell.

N-3 EARLY, H. C. and MARTIN, E. A., "The Underwater Spark; A Photographic Light Source of High Intrinsic Brilliance," Trans. Am. Inst. Elec. Engrs., Pt 1, 44, 788-790 (1955)

E-82 ECKSTEIN, L. and FREEMAN, I. M., "Das Spektrum explodierender Lithiumdrähte," Z. Physik 64, 547-555 (1930) (The Explosion Spectrum of Lithium Wires)

An attempt to solve some of the problems of E. W. P. by studying one of the simpler (alkali) spectra.

E-83 EDELSON, H. D. and KORNEFF, T., "A Comparative Study of Exploding Wires in Air and Water," J. Appl. Phys. 37, 2166-2168 (1966)

Wires exploded under water are apparently not surrounded by a luminous sheath, hence may be more accurately observed. The radial jets so noticeable in air photographs are still present. The gas column is dark during the dwell.

E-84 EDELSON, H. D. and KORNEFF, T., "Conducting Mechanisms for Exploding Wires in a Vacuum," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 267-284.

When a wire is exploded in a vacuum a discharge occurs in the region surrounding the wire. This discharge has been shown to occur in three phases: (1) the appearance of a sheath of plasma around the wire, rich in ultraviolet radiation, (2) ionization of the ambient atmosphere in the vacuum chamber, (3) the expansion of the plasma sheath into a cylinder of highly conducting vapor. Rogowski coils and biased gaps have been used to determine the distribution of current in this vapor cylinder and to show that it shunts 100% of the total current around the wire. Framing camera studies have shown that localized breakdown (e. g., end effect) may be involved in the formation of the sheath. It has been possible to produce a form of this plasma sheath at atmospheric pressure by producing localized breakdown near the corners of a bend in the wire.

E-85 EISELT, B., "Über den Ablauf von Drahtexplosionen," Z. Physik 132, 54-71 (1952) (The Course of Wire Explosions)

Comprehensive study of the theory of E. W. P. concentrating on a discussion of "dark time" and reason for reignition.

E-86 EISELT, B., "Über den Ablauf von Drahtexplosionen," Physik Ber. 30, 768-769 (1951) (On the Discharge from Wire Explosion)

Meeting report giving results written up in reference E-85.

E-87 ESCHENBACH, R. C., "Measuring Voltage in an Exploded Wire Discharge," Army Project 4A (July 1948)

Detailed discussion of methods of measuring voltage across an exploded wire. Describes many methods tried and the final satisfactory method.

E-88 FARADAY, M., "Division by the Leyden Deflagration," Proc. Roy. Instn 8, 356 (1857)

Mentions E. W. P. as a method of obtaining a very thin gold film.

E-89 FAUST, W. R., LEAVITT, G. E., SHIPMAN, J. D., Jr. and VITKOVITSKY, I. M., "Exploding Wire Studies," NRL Progress Rpt 1 Aug to 1 Nov 1962

Found X-rays generated inside imploded cylinders. Smear camera pictures study absorption of backlight by the plasma. The absorption was studied spectrographically. Cuts and a graph are included.

E-90 FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., VITKOVITSKY, I. M., HARRINGTON, F. D. and McMAHON, J. M., "Exploding Wire Studies," NRL Progress Report 1 May to 1 Aug 1962

A discussion of (1) high voltage low inductance puncture switch, construction and operating characteristics, (2) time resolved spectroscopy of E.W.'s, especially an analysis of Stark broadening of Al, Al* and Al**. Temperature and electron density determinations. (Temps up to 160,000°K), (3) a method of calibrating spectroscopic film from known film is described, (4) continuous emission, spectrum of E.W.'s, (5) a study of visible light output, (6) research to prevent breakdown across the holder, using nylon cylinders for liners and a redesigned holder.

N-4 FINKELBURG, W., "Continuous Electron Radiation in Gas Discharges," Phys. Rev. 45, 341-342 (1934)

X-14 FISH, B. R., ROYSTER, G. W., et al. "Aerosol Physics," in Health Physics Division Ann. Prog. Rep. 1963, K. Z. Morgan (ed), ORNL-3492 (1963) p. 185-193

A-10 FOITZIK, S., "Versuche mit grossen Stossströmen," Electrotech. Z. 60, 89-92; 128-133 (1939) (Experiments with Heavy Surge Currents)

E-91 FOURNET, M., "Phénomenes provoqués par des implosions de courant intenses dans des conducteurs résistants," Comptes Rendu 252, 2084-2086 (1961) (Phenomena Produced by Implosions of Heavy Current in Resistive Conductors)

Particles ejected by E.W.'s in vacuum are collected on a target and deductions made about velocity and thence about temperature. Velocity is reported to be 50 km/sec, 150-800 ev or 2,000,000°K. Cu-Ni alloy and graphite were exploded with 2μF and 5000 v.

E-92 FÜNFER, E., KEILHACKER, M., and [illegible]HNER, G., "Zum Mechanismus von Drahtexplosionen," Z. angew, Physik 10, 157-162 (1959) (On the Mechanism of Wire Explosions)

An investigation of energy-temperature relations in E.W.P. Parameters include length, cross-section of Cu, Ag. A consideration of energy balance and losses is included.

E-93 FUTAGAMI, T., "On the Electric Explosion Spectrum of Metals," Sci. Papers Inst. Phys. Chem. Research (Tokyo) 31, 1-29 (1937)

Description of equipment, electrical and photographic, used in many papers by author on E.W.P. Interest is primarily spectrographic. Tables and spectrographic plates are included.

M-8 FYFE, I. M. and EMSINGER, R. R., "Explosive Wire Induced Cylindrical Waves in Solids," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964), p. 257-265.

X-15 GARBUNDY, M., GOTTLIEB, M., and CONROY, J. J., "Hard Superconducting Films from Exploding Wires," J. Appl. Phys. 34, 3642-3643 (1963)

X-16 GERHARZ, R., "Zur Herstellung dünner Aluminumschichten in kurzen Bedampfzeiten," Z. angew. Physik 9, 95-98 (1957) (Preparation of thin aluminum films in short vaporization times)

E-94 GOL'TS, E. YA, and SADKOVICH, N. P., "Electric Explosion of Mercury Jet," Zh. eksp. teor. fiz. (Pis'ma) 2, 463-466 (1965) Trans. in JETP Letters 2, 288-289 (1965)

Description of a device for repetitive explosions of a mercury "wire". The Hg was expelled from a capillary. The switching was accomplished by moving an electrode toward the jet near the source. In this way current did not flow through the capillary.

D-2 GOOD, R. C., Jr., "Structural Response to Intense Electromagnetic Radiation," G. E. Space Science Lab. Report AFOSR-2483, First Annual Tech. Rep. (Feb 1962)

E-95 GOOD, R. C., Jr., "Resistance Variation of Exploding Wires," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 23-25

When fine wires are exploded by discharging a capacitor, the circuit exhibits damped electrical oscillations as an L-R-C circuit; however, the resistance varies during the explosion, which complicates the analysis. To date the resistance has been calculated either by integrating twice in succession the record of the rate of change of the current (1), or by the current-voltage method (2). A different approach is proposed in which the circuit equation is differentiated with respect to time and then solved by a method similar to the WKB method. The method is discussed, original data provided, and values of calculated resistances obtained by the double integration method is used to indicate the validity of the solution.

E-96 GOOD, R. C., Jr., "Surface Cracking Caused by Electromagnetic Wave Absorption," G. E. Co., Valley Forge Space Tech. Cent. Report, AFOSR-2295 (1962)

Exploded wire with 9600 joules at 80 KV into 2 mil W wire. Ringing freq. 300 Kc, 10 μs pulse.

Glass surface was damaged by the radiation (UV) from the wire. Study was made of the damage to the glass.

E-97 GORDIENKO, V. P., and SHNEERSON, G. A., "Electrical Explosion of Skin Layer," Zh. Tek. Fiz. 34, 376-378 (1964)

The authors find the surface of a Wood's metal solenoid explodes off long before any deformation occurs. The resulting material is vaporized not mechanically eroded.

J-4 GOSS, W. C., "Kerr-Cell Framing Camera," V. Internat. Congress on High Speed Photog., Washington, p. 135-137 (1960)

X-18 GZYLEWSKI, J., LAS, T., BEDNARSKI, T., "Zastosowanie stomych pradow udarowych do hydrodynamicznego i magnetycznego formowani a metali," Przeglad Elektrotechniczny 41 (4): 121-125 (1965) (The Application of Steep Pulse Currents to the Electrodynamic and Magnetic Forming of Metals)

E-98 HALLOWES, J. P., Jr., "Generation of Fast Waveforms," Res. Labs., Quart. Res. Rev. 17, 88-97 (1958) Army Rocket and G. M. Agency

The author suggests E. W. P. to generate fast waveforms. Very general analysis of the mechanism attempted.

M-9 HALPIN, W. J., and HENDRICKS, R. E., "The Use of Pressure Bars and Plates for the Investigation of Shock Waves from Electrically Exploded Wires," Sandia Tech. Memo SCTM 39-60 (51) (1960)

T-2 HÄNDEL, S. K., STENERHAG, B., and HOLMSTROM, I., "Hard X rays from Exploding Wires," Nature 209, 1227-1228 (1966)

X-19 HARRAWAY, R. A., "An Exploding Wire Triggered Spark Gap," J. Sci. Instr. 41, 399 (1964)

E-99 HAUVER, G. E., "A Spectrograph with Space-time Resolution and Its Application to the Study of Exploding Tungsten Wires," BRL Report 913 (July 1955)

Using framing rotating mirror camera as a spectrograph, changes in spectrum with time were studied. Early stages mostly air spectrum; later tungsten.

E-100 HEGE, J. S., "Determination of the Total Thermal Radiant Energy Emitted by an Underwater Exploding Wire," USN Radiological Def. Lab., USNRDL-TR-612 (Jan. 1963)

Total thermal radiation from an underwater spark generated by exploding a 5 mil wire was determined by graphically integrating the rate of thermal radiation over time. Approx. 30% of spark energy was radiated. Light was measured by photoelectric tubes at 407 and 610 millimicrons.

J-5 HEINE-GELDERN, R. V., "Photographie Ultra-Rapide au Moyen de Cellules de Kerr et de Fils Explosifs," Photographie and Cinématographie Ultra-Rapides, Actes du 2 ème Congress International de Photographie et Cinematographie Ultra-Rapides, Paris (1954) p. 238-243 (High-Speed Photography by Means of Kerr-cells and Exploding Wires)

J-6 HEINE-GELDERN, R. V., PUGH, E. M. and FONER, S., "Kerr Cell Photography of High Speed Phenomena-Detonation and Shock Phenomena," Phys. Rev. 79, 230 (1950)

E-101 HERZOG, A., "Influence of Short Time, High Velocity Impact on Materials Structures," Tech. Memo WCRT-56-93, Wright Air Development Center, Materials Laboratory (Aug 1956)

Use of E. W. P. to produce shock, temperature, and particle effects on Al, Cu, and an alloy of Mo-98/W-2. Discussion and metallographic photographs.

J-7 HOLTZWORTH, R. E. and HINZ, D. J., "Exploding Wire Backlighting for the Study of Detonation, Shock and Shaped Charges," BRL Report 818 (May 1952)

E-102 HORI, T., "On the Absorption Spectra Produced by the Explosion of Various Elements, (Hg, Cu, Fe, etc.)," Sci. Papers Inst. Phys. Chem. Research (Tokyo) 4, 59-78 (1926)

A study of absorption spectra of exploding wires.

E-103 HOBSON, A. and MANKA, C. K., "Premelt Variation of Current, Temperature, and Resistance in Exploding Wires," J. Appl. Phys. 37, 1897-1901 (1966)

The RCL condenser discharge equation, modified to account for changing resistance of the E. W. was solved in a 2 term approximation. Assumptions were (1) wire heats homogeneously, (2) no current shunted around wire (3) all energy used by wire, heats wire, (4) all components except wire constant. The 2 term solution by perterbation method agrees well with experiment during first 1/5 cycle for a Ni wire with no dwell.

Q-7 HUBER, H., "Technical Specifications of an Exploding Wire Triggered Solid Dielectric-Switch,", Stevens Inst. Tech. SIT P-78 (1/63)

E-104 v. HÜBL, A. and v. OBERMAYER, A., "Über einige elektrische Entladungser scheinungen und ihre photographische Fixierung," Sitzungber d. K. Akad. Wissensch. zu. Wein 98, Abth IIa, 419-430 (1889) (On the Appearance of Several Electrical Discharges, and their Photographic Recording)

Photographs and smoke plate recordings of E. W. P. and sparks. Recorded the "normal" rays which would now be called jets.

X-20 JONCICH, M. J. and REU, D. G., "Synthesis of Inorganic Binary Compounds Using Exploding Wire Techniques," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 353-359

X-21 JONCICH, M. J. and VAUGHN, J. W., "Chemistry at 1 Million °K," New Scientist 25, 716 (1965)

E-105 JONCICH, M. J., VAUGHN, J. W., and KUNTSEN, B. F., "Preparation of Metal Nitrides by the Exploding Wire Technique," Canadian J. Chem. 44, 137 (1966)

A record of results of exploding various metals in gaseous N_2, liquid N_2, NH_3, mixture of $H_2 + N_2$. Nitrides were detected by a Kjeldahl analysis. Metals studied were: Mg, Ti, Zn, Ta, Fe, Rh, Pt, Cu, Zn, Al, Cd.

M-10 JONES, D. L., "Precursor Electrons Ahead of Cylindrical Shock Waves," Phys. Fluids 5, 1121-1122 (1962)

M-11 JONES, D. L., and EARNSHAW, K. B., "A Wire Exploder for Generating Cylindrical Shock Waves in a Controlled Atmosphere," N. B. S. Technical Note No. 148 (Feb 1962)

M-12 JONES, D. L., and GALLET, R. M., "Microwave Doppler Measurements of the Ionization Front in Cylindrical Shock Waves from Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 127-144

E-106 KARIORIS, F. G., and FISH, B. R., "An Exploding Wire Aerosol Generator," J. Colloid Sci. 17, 155-161 (1962)

E. W. technique used to produce aerosols of noble metals and of base metal oxides. Apparatus is described and results are given briefly for 16 metals and in detail for uranium.

E-107 KARIORIS, F. G., FISH, B. R., and ROYSTER, G. W., Jr., "Aerosols from Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 299-311

A large fraction of an exploded wire can be recovered reproducibly from the solid aerosol disperse phase produced by explosions at various voltages (1 to 18 kv) on a 20 μf capacitor bank. Typical smokes consisting of oxide particles are produced by explosions of base metals in air and fine metallic particles are produced by the explosion of Ag, Au, and Pt in air or by Al and Cu exploded in argon. Primary particle size and size distribution are related to the voltage used for the explosion. Aerosol-yield curves for copper and uranium are discussed in the light of previously described exploding wire phenomena. The method is well suited for the production of small quantities of solid aerosols.

X-23 KARIORIS, F. G., and WOYCI, J. J., "X-Ray Investigation of Aerosols from Wires Exploded in Nitrogen," XII Ann. Conf. on Appl. of X-ray Analysis (Aug 1963) p. 240-251

X-24 KARIORIS, F. G., and YOUNGBLOOD, J. W., "Aerosol Generator," in Health Physics Annual Prog. Rpt. 1961, K. Z. Morgan (ed), ORNL-3189, p. 227-229 (1961)

E-108 KATZENSTEIN, J. and SYDOR, M., "The Exploding Wire as Fast Dynamic Pinch," Univ. of N. Mex. Final Tech. Report (July 1961)

Explosions of 1 mil Cu, Li, Li-H, Li-H^2 graphite coated polyethylene were studied by streak camera, framing camera, current, and neutron detector. Low Z materials act much differently from high Z. Photographic and neutron evidence of pinch appears with the low Z materials. An unexplained dark area appears in the pinch photos. This may be due to bremsstrahlung with guillotining. Temperatures of about 300 ev were estimated.

E-109 KATZENSTEIN, J., "The Pinch Effect in the Exploding Wire Phenomenon," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 135-146

Streak camera studies of 2 mil Cu wires in a coaxial system. A current oscillogram was synchronized with the photos.

E-110 KATZENSTEIN, J., and SYDOR, M., "Exploding Wire as Fast Dynamic Pinch," J. Appl. Phys. 33, 718-723 (1962)

See E-108

E-111 KEILHACKER, M., "Über den Mechanismus der explosions-artigen Verdampfung von Kupferdrähten durch sehr intensive Stromstösse und das Verhalten des Kupfers bei den dabei auftrentenden hohen Drucken und Temperaturen," Z. angew Physik 12, 49-59 (1960) (On the Mechanism of Explosive Vaporization of Copper Wires by Very Large Current Pulses and the Behavior of Copper at the Resulting High Pressures and Temperatures)

The author measures current, voltage, and light intensity output and compares the results with his calculations of temperature, pressure, energy absorbed. He uses Himpan's equation of state for copper and gets his critical data from David's estimates. He proposes a mechanism in which the Cu superheats and the superheat is broken by an inward progressing rarefaction wave.

E-112 KERSAVAGE, J. A., "Pressure Environments Created by Wires Exploded in Water," Exploding Wires, Vol. II Chace and Moore (eds), Plenum Press, New York (1962) p. 225-233

This paper presents the results of experiments in which a capacitor discharge circuit was used to explode a 3-in. length of thin wire submerged in fresh water, and the resulting pressure at a particular range was recorded as a function of time, using calibrated hydrophones and oscilloscopes. The entire pressure sequence of initial pulse and subsequent bubble pulses is discussed. The effect on the shape and amplitude of the initial pressure pulse of varying discharge circuit conditions such as initial capacitor voltage, total capacitance, and inductance is also presented.

E-113 KESSLER, M., "Conception and Installation of an Electrical High Energy Discharge Unit," Watertown Arsenal Lab. WAL TN 126. 1/1 (Oct. 1962)

The background and motivation for installing an electrical high energy discharge unit are presented, followed by a description of the equipment. Initial experimentation is discussed and illustrated. Future plans concerning electrohydraulic forming ("Spark Forming"), the metallurgy of high energy rate loaded metals, and exploding wire studies are outlined. Raising the power of the installation to its originally designed value is also planned. Availability of the installation to personnel interested in conducting research on materials is announced.

Wires used: Ti 4-10 in. long, 0.031 in. dia. Six inch wire was the most effective for 4 in. dia.

B-3 KING, A. S., "Spectroscopic Phenomena of the High Current Arc," Astrophys. J. 62, 238-264 (1925)

E-114 KLEEN, W., "Über den Durchgang der Elektrizität durch metallische Haardrähte," Ann. Physik, 11, 579-605 (1931) (On the Passage of Electricity thru Fine Metal Wires)

A detailed study of E. W. P. with capacity as the principal variable, photography - including rotating mirror - the principal instrument. Explains vapor stria by prior formation of unduloids in the liquid phase.

X-27 KONSTANTINOV, B. P., ZIMKIN, I. N., STEPANOV, M. I. and SHESTOPALOV, L. M., "Hardening of Steel Surface by Wire Explosion," Fizika metallov i metallovedeniye 22, 157-158 (1966)

E-115 KORNEFF, T., BOHN, J. L. and NADIG, F. H., "Exploding Wire Phenomena at Reduced Pressures," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 104-117

A study of E. W. particularly during dwell by framing camera. Wires of Cu, B+S No. 24 and 40, were exploded in a vacuum and at atmospheric pressure. Differences in manner of restrike were noted for 24 and 40. At reduced pressures, arc-over around wire is the important feature; down to 1 mm arc-over is in the air; below this in the vapors produced by the heated wire.

E-116 KORNEFF, T., CHACE, W., and EDELSON, H. D., "Shunting Mechanisms in Exploding Wires at Reduced Pressures," VI Internat. Conf. Ionization Phenom. in Gases, Paris, Vol. II, p. 627-631 (1963)

The authors study shunting with probes, Rogowski coils, and high-speed photos. They conclude that there are three distinct processes: (1) ionization of amibient atmosphere by U. V., (2) ionization by suddenly applied electric field when current goes to zero, and (3) material carried from wire at shock speed.

M-13 KOTOV, Yu. A. and MEL'NIKOV, M. A., "Recording Shock Waves and Exploding Wire Characteristics," Elektronnaya obrabotko materialov No. 3, 28-32 (1966)

E-117 KUL'GAVCHUK, V. M., "Development of Luminous Zones in Electrical Detonation of Thick Wires," Zh. Priklad. Mekh. i Tekhnich. Fiz. 4, 165-168 (1965)

The authors study the luminous zone around the wire, concluding that it is coincident with the shock wave front. Energy input was calculated from voltage drop in the condenser. They conclude that the luminous zone follows the law of motion of a cylindrical shock. They also calculate the fraction of the wire vaporized.

X-28 KUL'GAVCHUK, V. M., "Producing Powerful Radio Pulses by the Electric Explosion of Metal Wires," Pribary i tekhnika eksperimenta No. 1, 132-137 (1965)

E-118 KUL'GAVCHUK, V. M. and NOVOSKOL'TSEVA, G. A., "X-Ray Study of Kinetics of Heating and Evaporation of Exploding Wires," Zh. tek fiz. 36, 549-556 (1966) (Trans. in Soviet Physics-Tech. Phys. 11, 406-412 (1966)

Working in the "slow explosion" regime the authors expiain dwell and stria by a modified unduloid method. X-Rays are used for study of behavior. The vapor sheath is explained as a vapor cloud formed by evaporation of the wire.

E-119 KUL'GAVCHUK, V. M., SHISHKIN, Yu. B., BEREZIN, I. A., "Measurement of the Temperature in the First Stage of the Electrical Explosion of Wires," Teplofizika vysokikh temperatur, v 4, No. 3. 419-423 (1966)

Experimental determination of warm-up time, emission time, and color temperature of Cu, Ag, constantan, at two levels of circuit inductance 0.058 μH and 1.7 μH.

E-120 KVARTSKHAVA, I. F., "Concerning Papers of E. S. Khaikin, S. V. Lebedev and B. N. Borodovskia Published in the Zhur. Eksp. i Teoret. Fiz. (USSR) in 1954-1955," Zhur. Eksp. i Teoret. Fiz. 30, 621 (1957); Soviet Phys. JETP 3, 787 (1956)

Kvartskhava feels that the anomalous state postulated by Lebedev, Khaikin and Borodovskia is not sufficiently supported by experimental evidence. Also he doubts Lebedev's measurements on E. W. P. especially voltage measurements. Kvartskhava thinks abnormality may be accounted for by motion of the wire.

E-121 KVARTSKHAVA, I. F., BONDARENKO, V. V., MELADZE, P. D. and SULADZE, K. V., "Electric Explosion of Spiral Wires in Vacuum," Zhur. Eksp. i Teoret. Fiz. 35, 911-916 (1958), Trans. in Soviet Phys. JETP 35, 634-638 (1959)

Various bent wires were exploded and photographed. Action of explosion products were noted and the result analyzed. Radial ejection of explosion products confirmed. Current tubes formerly seen are reconfirmed and used to explain bent wire action.

E-122 KVARTSKHAVA, I. F., BONDARENKO, V. V., PLIUTTO, A. A., and CHERNOV, A. A., "Oscillographic Determination of Energy of Electric Explosion of Wires," Zhur. Eksp. i Teoret. Fiz. 31, 745-751 (1956) Soviet Phys. JETP 4, 623-629 (1957)

Studies resistance changes and proposes "energy leakage" and relates this to material expelled in the radial jets. Measures velocities of 10^6 cm/sec.

E-123 KVARTSKHAVA, I. F., BONDARENKO, V. V., MELADZE, P. D., and SULADZE, K. V., "Electrical Explosion of Wires in Vacuum," Zhur. Eksp. i Teoret. Fiz. 31, 737-744 (1956), Soviet Phys. JETP 4, 637-644 (1957)

Studies were made from time integrated photographs and vapor deposits. The authors find explosion in vacuum is a combination of a real E. W. P. and an arc around the wire. Magnetic pinch is discussed.

E-124 KVARTSKHAVA, I. F., PLIUTTO, A. A., CHERNOV, A. A., and BONDARENKO, V. V., "Electrical Explosion of Metal Wires," Zhur. Eksp. i Teoret. Fiz. 30, 42-53 (1956), Soviet Phys. JETP 3, 40-51 (1956)

Shadow photography, oscillography of current and voltage, also photometry are used to study E. W. P. Theory developed postulates pressure developed in wire due to heating and little time to expand. Interruption of current flow due to shock waves along the wire which cause cavitation and open the circuit. Melting is in beads. Evaporation starts between the beads.

X-29 LA COSS, W. D., "A Qualitative Study on an Exploding Wire Fuse," Sandia Corp. SCTM 145-61 (14) (Aug 1961)

E-125 LANDER, J. J. and GERMER, L. H., "The Bridge Erosion of Electrical Contacts - Part I," J. Appl. Phys. 19, 910-928 (1948)

Used E. W. P. to study melting phenomena. Important because of melted metal bridges formed on opening contacts.

E-126 LANGWORTHY, J. B., O'ROURKE, R. C., SHULER, M. P. VITKOVITSKY, I. M., DOBBIE, C. B., VEITH, R. J. and HANSEN, D. F., "Electrically Exploded Wires - Experiments and Theory," Progress Rept. 1/III/58 to 30/VI/60. NRL Rept. 5489 (1961)

The report discusses: (1) the design, construction, and operation of the three capacitor systems for use on exploding wires; (2) an elementary theory of the processes which might occur in an exploding wire and, where possible, numerical examples; (3) electronic instrumentation which includes traveling-wave scope techniques for measuring current and power in exploding wires with 10^{-9} sec resolution; (4) optical instrumentation which involves a streak camera, an ultra-high-speed streak spectrograph, and a grating

streak spectrograph which has high spectral resolution. Included are some preliminary experimental results.

E-127 LAPPLE, H., Electric Fuses, A Critical Review of Published Information, Butterworth, London (1952)

A qualitative discussion of fuses from European points of view. A fully annotated bibliography including several references to E. W. P.

E-128 LEBEDEV, S. V., "Initial Heating Stage of Exploding Wires," Zh. eksp. i teor. Fiz. 50, 509-519 (1966), Trans. in Soviet Physics JETP 23, 337-343 (1966)

A reconsideration of the diode experiments carried out by the author 1954-1957. The Anomolous anode current is again the chief topic of study.

E-129 LEBEDEV, S. V., "Reply to Critical Remarks of I. F. Kvartskhava Concerning our Papers," Zhur. Eksp. i Teoret. Fiz. 32, 144-145 (1957) Soviet Phys. JETP 5, 126-127 (1957)

As indicated, an answer to the criticism printed in Zhur. Eksp. i Teoret. Fiz. 30, 621 (1956) and translated in Soviet Phys. JETP 3, 787 (1956) (ref E-120). Mostly Lebedev feels that Kvartskhava misinterpreted his papers.

E-130 LEBEDEV, S. V., "Explosion of a Metal Due to an Electric Current," Zhur. Eksp. i Teoret. Fiz. 32, 199-207 (1957), Soviet Phys. JETP 5, 243-252 (1957)

Using data from 3 μsec Faraday shutter pictures, coupled with I and E oscillograms at two energy levels (5×10^5 A/cm^2 and 5×10^6 A/cm^2), the author postulates that anomalous results are due to disturbance of bonds in metal. Mostly W wire.

E-131 LEBEDEV, S. V., "Phenomena in Tungsten Wires Preceding their Disintegration under the Effects of Heavy Current," Zhur. Eksp. i Teoret. Fiz. 27, 605-614 (1954)

The phenomena described is similar to an E. W. P. just before the wire explodes.

K-7 LEBEDEV, S. V. and KHAIKIN, S. E., "Some Anomalies in the Behavior of Metals Heated by Current Pulses of Great Density," Zhur. Eksp. i Teoret. Fiz. 26, 629-639 (1954)

W-3 LEIGH, C. H., "Exploratory Research on the Vaporization of Solids," AVCO, Res. and Adv. Develop. Div. Tech. Rept. RAD-TR-62-19 (1962)

P-9 LEJEUNE, J. M., "Applications de la methode d'explosion de fils minces à l'étude du spectre de CaO," Bull. Soc. Roy. Sc. Liege 14, 318-322 (1945) (Applications of the method of exploding wire to the study of the spectrum of CaO)

Eb-15 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires," U.S. Naval Ordnance Lab. NOLTR 63-159 (1963)

Eb-16 LEOPOLD, H. S., "Photographic Studies of Growth of Explosion," U.S. Naval Ordnance Lab. NOLTR-62-86 (1962)

E-132 LESNIK, A. G., "Concerning One Necessary Condition for the Vaporization of a Metal Wire By Exploding it with Current," Dokl. Akad. Nauk SSSR 17D, 1059-1061 (1966)

> Wire must be raised above critical temperature and pressure if there is to be a homogeneous vapor. The author gives a differential equation relating electric charge, inductance, magnetic pressure, temperature, and other parameters which is formulated and solved by computer. Magnetic pressure is strong function of wire diameter.

J-8 LEVINE, M. A., and HEGARTY, J. C., "Shadowgraph of Self-Luminous Objects," Applied Optics 2, 78 (1963)

E-133 LEVINE, P. H., TOLLESTRUP, A. V., and WEBB, F. H., Jr., "Electrical Conduction in Rapidly Exploded Wires," Vol. II, p. 2034-2053, V Internat. Conf. on Ionization Phenom. in Gases, Munich (1961)

> Time history of wire resistance is obtained and scaling properties investigated for various materials exploded in $< 10^{-7}$ sec with peak specific powers of 5×10^{12} to 2×10^{14} watts/mol.

F-3 LEWIS, M. R., and SLEATOR, D. B., "Exploding Wire Light Source for High Speed Interferometry," Ballistic Res. Lab. Memo Rep. No. 975 (Feb 1956)

LIDDIARD, T. P. and DROSD, R. D., "Exploding Wires for Light Sources in Fast Photography," U.S. Naval Ordnance Lab. Memo 10840 (1950)

J-10 LIEBING, L., and FRÜNGEL, F., "Multiple Kerr-Cell System with Square Shuttering Characteristics," V. Internat. Congress on High Speed Photog., Washington, p. 138-140 (1960)

R-6 LOCHTE-HOLTGREVEN, W., "Production and Measurement of High Temperatures," Repts. Progr. Phys. 21, 312-383 (1958)

E-134 LOCHTE-HOLTGREVEN, W., "Über die Elementarvorgänge bei der elektrischen Explosion dünner Metalldrähte," Tagung über Verbrennung, Stosswellen, Detonation, St. Louis (1951), Laboratoire de Research de St. Louis (France) 14/M/51 325-337 (1951) (Concerning the Elementary Processes in the Electrical Explosion of Thin Metal Wires)

The author divides the E.W.P. process into four periods, (1) Heating and vaporizing, (2) Nonconducting period, (3) Restrike of arc initiated by shock waves, (4) Oscillatory discharge. This article postulates superheating and shockwaves as important features. Mentions the use of Schlieren photographs in the experimental part.

P-10 LOGINOV, V. A., "The Production of Electronic Band Spectra by the Exploding Wire Method," Optika i Spektroskopiya 16, 402-403 (1964), Trans. in Optics and Spectroscopy 14, 220-223 (1964)

A-13 LOGINOV, V. A., "Set-up for Studying Electron Absorption Spectra by Electrical Bursting of Wires Immersed in Water," Pribory i tekh eksper. No. 1, 171-173 (1964)

E-135 LOGINOV, V. A., "Production of the Absorption Spectrum of A 1 O by the Method of Electrically Exploding a Wire in Air at Atmospheric Pressure," Optika i Spektroskopiia 6, 111-113 (1959), Trans. in Optics and Spectroscopy 6, 67-68 (1959)

Apparatus explodes wire and produces intense spark in a hole in textilite for background, then explodes wire in air for the spectrum.

E-136 LUNDQUIST, S., "Some Observations on High-Current Channels in Air with Application to Lightning Discharge," Arkiv f. Fysik 31, 173-176 (1966)

The author is studying the current-radiant energy relation of an E.W.P. to get data on lightning. The radiation pulse follows the current pulse on the rise, but decays much more slowly.

E-137 MAHIEUX, F., "Reactions Chimique par explosion de fils metalliques. Synthese de l'hexafluoroplatinate de xenon," Compte Rend. 257, 1083-1086 (1963) (Chemical reactions brought about by the explosion of metal wires)

By exploding various wires (Cu, Pt, Ag, Al, Ni) in a small flask with different gases (Air, N_2, O_2, O_3 CFC_3) a large number of situations was studied. The 16μF condensers were charged to 2 kV and did not give a true explosion in most cases, but dispersed the wire into small droplets. Pt exploded in a mixture of F and Xe produced a red orange deposit which may be Xe Pt F6.

E-138 MANINGER, R. C., "Preburst Resistance and Temperature of Exploding Wires," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 47-64

Section E

It has been shown that the time of burst of exploding wires can be predicted from known thermodynamic and electrical properties of the wire materials under some conditions. The mathematical relationships are a set of integrals (transformation time integrals) similar in form to the empirical "action integrals" sometimes used in exploding wire work. This paper discusses the use of the transformation time integrals to calculate the resistance and temperature of a wire as a function of time up to the time of burst and to investigate the effects of environment of the wire on the temperature, resistance, and time of burst.

E-139 MANINGER, R. C., "Preburst Resistance and Temperature of Exploding Wires," U. of Cal. (Livermore) UCRL-7613 (1964)

Transformation time integrals can be used to calculate time to burst of E.W.'s. This paper discusses use of transformation time integrals to calculate resistance and temperature vs. time up to time of burst, and to investigate effects of environment on temp, resistance and time to burst.

S-3 MANINGER, R. C., "Effects of Transmission Lines in Applications of Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 109-126

C-3 MANINGER, R. C., "Radial Distribution of Current and Its Effect in an Exploding Wire," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 156-159

X-31 MARCUS, R. A., "Application of the Exploding Wire Technique in Photochemistry," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 307-314

N-7 MARTIN, E. A., "Experimental Investigation of a High-Energy Density, High Pressure Arc Plasma," J. Appl. Phys. 31, 255-267 (1960)

N-8 MARTIN, E. A., "The Underwater Spark: An Example of Gaseous Conduction at about 10,000 Atmospheres," Univ. of Michigan 2048-12-F (July 1956)

B-4 MAURY, E., " Phénomènes consécutifs à un court-circuit provoqué par un fil fusible sur un réseau à 220 kilovolts," Rev. Gen. Elec. 54, 131-138 (1945) (Phenomena resulting when a short-circuit is produced on a 220 kV network by a fusible wire)

R-7 MAYFIELD, E. B., "Radiometric Temperature Measurements of Exploding Wires," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 147-155

E-140 MEDVED, D. B. and TURNBULL, W., "Microwave Absorption of Exploding Wire Plasmas," Bull. Am. Phys. Soc. 7, 441 (1962)

E. W. monitored with Ku (16,500 mc). 2 mil Cu wire parallel mounted in wide axis of rectangular wave guide operating in TE_{10} mode. Transmission $|T|^2$ and reflection $|R|^2$ are measured along with I and V in wire. 5J dumped in 0.2 μsec. Dwells of 5-20 μsec. $|T|^2$ drops 1 db during dwell is constant. At restrike it drops to <1%. Recovers in about 400 μsec. (Meeting paper)

E-141 MEDVED, D. B., TURNBULL, W., and LIPSCOMB, E. T., "Interaction of Microwaves with Exploding Wires," Phys. Fluids 5, 1309-1310 (1962)

Observations of microwave absorption during dwell confirm current flow. Very large reflection occurs at restrike. The apparatus used is described. Ku band microwaves were used and a 2-mil, 2.5-cm-long wire exploded at 20 kV.

E-142 MEL'NIKOV, M. A. and BARCHENKO, T. N., "On the Influence of Circuit Parameters on the Process of the Electrical Explosion of Wires," Izvestiia Vysshnikh Uchebnykh Zavedenii, Fisika No. 4, 39-45 (1965)

An investigation of the effect of varying in turn size of wire, capacity of bank, voltage, switch, wire material (constantan, nichrome, copper), length of cable between wire and bank. The results are presented graphically. All the results confirm what might have been expected.

E-143 MEL'NIKOV, M. A., and OBUKHOV, V. I., "Oscillographic Investigation of Electrical Wire Explosions," Izvestiia Vysshikh Uchebnykh Zavedenii. Energetika, 99-102 (1963)

A study of energy in E. W. as wire resistance R(t) and wire to storage system resistance R(g) was changed. As might be expected greater energy was deposited in the wire as R(t)/R(g) was decreased.

P-13 MENZIES, A. C., "Shifts and Reversals in Fuse-Spectra," Proc. Roy. Soc. (London), A117, 88-100 (1927)

M-15 MICHEL-LEVY, A., and MUROAUR, H., "Sur la luminosité des ondes de choc" Comptes-Rend. 198, 1760-1762 (1934) (Concerning the Luminosity of Shock Waves)

E-144 MOESTA, H. and BREWER, D., "Liquid Metal as an Exploding Wire for Repeatable Operation in Vacuum Work," Rev. Sci. Instr. 36, 1372-1373 (1965)

A jet of liquid metal (Sn) is ejected upward from the lower electrode to a flat plate upper electrode. The jet explodes as a wire to act as a light source.

E-145 MORAN, K. E., "Direct Vapor Deposit Recording of Exploding Wire Phenomena," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 285-294

When a paper surface is held within 100 diameters of an exploding 0.08 mm (0.0031 in.) nichrome wire, an image is made directly on the paper. In preliminary work, sharp reaction interfaces were recorded within the energy range of 5 to 50 J and the pressure range of 100 to 5000 torr. The method used and some relationships are presented along with some of the interesting complex vapor deposits obtained by this recording technique.

E-146 MOSES, K. G., and KORNEFF, T., "The Application of P. W. Bridgman's 'New emf' to Exploding Wire Phenomena," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 37-46

P. W. Bridgman propounded the possible existence of a 'new emf' generated in a conductor carrying a current due to a time-varying temperature. By means of thermodynamical arguments Bridgman deduced that the emf generated is given by

$$V_B = - \frac{L1}{H} \frac{dH}{dT} \frac{dT}{dt}$$

This emf was not detected by any researchers due to the fact that the magnitude of this generated voltage is very small under normal conditions. However, under the conditions of an exploding wire the magnitude of the emf can become increasingly important. It is shown in this paper that this effect can possibly account for the excess energy required to melt and vaporize a wire under the extreme conditions of a rapid discharge.

Q-10 MOSES, K. G., and KORNEFF, T., "The Nonlinear Effects of an Air Gap Switch in Exploding Wire Circuits," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 391-404

E-147 MULLANEY, G. J., BROWN, E. A., Jr., and AHLSTROM, H., "Exploding Wire Study," Boeing Sci. Res. Lab. Rev. 14, 20-22 (1965)

Description of background and plans for study of coupling of energy from wire explosion to surrounding gas. Find metal shock not primary mechanism of energy transfer to gas.

Eb-19 MULLER, G. M., MOORE, D. B., and BERNSTEIN, D., "Growth of Explosion in Electrically Initiated RDX," J. Appl. Phys. 32, 1065-1075 (1961)

E-148 MÜLLER, W., "Studies of Exploding Wire Phenomenon by Use of Kerr Cell Schlieren Photograpny," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 186-208

The phenomenon of E.W.'s has been studied by Kerr Cell Schlieren photography. Pictures show the shock wave system, the formation of dwell, and reignition.

E-149 MÜLLER, W., "Der Ablauf einer electrischen Drahtexplosion mit Hilfe der Kerr-Zellen-Kamera untersucht," Z. Physik 149, 397-411 (1957) (Results of an Electric Wire Explosion Investigated by Means of the Kerr Cell Camera)

Used a double Kerr-Cell camera, with knife edges placed in the light path to produce schlieren results. This allowed a study of shock waves in and around the explosion. Detailed descriptions of the equipment and experimental procedure as well as results and analysis are given.

X-32 McFARLANE, H. B., "A High-Voltage, Quick-Acting Fuse, to Protect Capacitor Banks," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 324-344

E-150 McGRATH, J. R., "Scaling Underwater Exploding Wires," J. Appl. Phys. 37, 4439-4443 (1966)

A comparison of underwater explosion of wires and chemical (TNT) explosives. Peak pressure and decay time constant of the shock wave are compared. It is found that peak pressure reduces to the same kind of similitude functions as those used for TNT if circuit losses are included. Reduced time constant also reduces to same kind of similitude function. Magnitude and behavior of reduced time constant are comparable to TNT.

J-13 NADIG, F. H., BOHN, J. L., and KORNEFF, T., "High Speed Framing Camera for Photographing Exploding Wire Phenomena," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 345-364

E-151 NAGAOKA, H. and FUTAGAMI, T., "Cinematographic Sketch of Electrically Exploded Wires," Proc. Imp. Acad. (Japan) 4, p. 198-199 (1928)

Brief description of the camera which used a double slit shutter. Total exposure 384 microseconds, 14 microsecond exposures.

E-152 NAGAOKA, H. and FUTAGAMI, T., "Electric Explosion in Magnetic Field," Proc. Imp. Acad. (Japan) 4, 283 (1928)

Repeated work reported in E-151 in a magnetic field and noted significant differences.

E-153 NAGAOKA, H., and FUTAGAMI, T., "Electric Explosions," Sci. Papers Ins. Phys. Chem. Res. (Tokyo) 8, 269-288 (1928)

Description of apparatus and techniques for explosions. Used drum camera and framing camera. Eleven plates of photographs with descriptions. Explosions in oil with an attempt to cause transmutation. Little theoretical material.

E-154 NAGAOKA, H., and FUTAGAMI, T., "Instantaneous Photographs of Electrically Exploded Wires," Proc. Imp. Acad. (Japan) 2, 387-388 (1926)

Photographs taken with rotating drum camera. No explanation of phenomena observed.

E-155 NAGAOKA, H., FUTAGAMI, T., and MACHIDA, T., "Electric Explosion of Wires and Threads," Proc. Imp. Acad. (Japan) 2, 328-329 (1926)

Photographs of slow and fast explosions of wires and solution saturated threads.

P-14 NAGAOKA, H., NUKIGAMA, D., and FUTAGAMI, T., "Instantaneous Spectrograms," (various metals) Proc. Imp. Acad. (Japan) 3, 208-212, 258-264, 319-333, 392-418, 499-502 (1927)

P-15 NAGAOKA, H., and FUTAGAMI, T., "Explosion Spectra of Mercury," Proc. Imp. Acad. (Japan) 2, 254-257 (1926)

P-16 NAGAOKA, H., FUTAGAMI, T., and OBATA, H., "Spectra of Metals Excited by Means of High Tension and Heavy Current," Proc. Imp. Acad. (Japan) 2, 161 (1926)

E-156 NAIRNE, E., "Electrical Experiments by Mr. Edward Nairne," Phil. Trans. Roy. Soc. (London) 64, 79-89 (1774)

Description of the static machine, the 64 jar leyden jar condenser bank and experiments with exploding wires, electrocution of fowl and effect of electricity on plants. Studied conditions in series circuits and what we now call self-inductance. Fascinating historical paper.

E-157 NASH, C. P., and McMILLAN, W. G., "On the Mechanism of Exploding Wires," Phys. Fluids 4, 911-917 (1961)

Measurement of condenser voltage, di/dt,dwell, and shock energy. Explosions were made in He, N_2, O_2, and $CClF_3$. A theory is proposed for the dwell based on Bardeen's theory of metallic resistance. The temp and "compression" changes can be made to account for the resistance increase found by the authors. A hydrodynamic model is proposed for a restrike from the dwell situation, based on spark breakdown mechanism.

E-158 NASH, C. P., and OLSEN, C. W., "Initial Phase of the Exploding Wire Phenomenon," Phys. of Fluids 7, 209-213 (1964)

An approximate solution of the condenser discharge equation is effected using a linear resistance rise. Inductive effects govern first pulse energy in small-diameter wires, thermodynamic effects are important for large-diameter wires. The importance of heat of vaporization, resistivity and temp. coeff. of resistivity are brought out.

E-159 NASH, C. P., and OLSEN, C. W., "Factors Affecting the Time to Burst in Exploding Wires," in Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 5-13

Time to burst studied in relation to various parameters — energy, cross-section, length, voltage. No satisfactory theory is proposed.

It is suggested that r/r_o must reach some critical value, depending on the material. Order of time to burst is Pb < Al < Au < Ag < Cu≈ Pd. A linear relation exists between cross-sectional area and time to burst for Al at constant initial voltage.

E-160 NASILOWSKI, J., "Unduloids and Striated Disintegrated Wires," in Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 295-313

The paper describes a method for the production of unduloids and the results of investigations of unduloid spacing. Only thin wires are transformed into unduloids; thick wires rupture into segments, which indicates a possible vibrational process. Existence of vibrations in wires during explosion was confirmed by direct measurements. Studies of the internal texture of the unduloids and segments indicated that the wires melt from the surface inward. X-ray investigations of fuses after their operation showed a striated picture of metal deposits in quartz-sand. The spacing of striations is different in character and magnitude than the spacing of unduloids, which suggests that they are caused by different physical processes.

E-161 NASILOWSKI, J., "Elektromagnetyczne sciskanie odorobnionego przewodu wiodqcego prqd.," (Electromagnetic Compression of an Isolated Wire through which an electric current is flowing) Przeglad Elektrotechniczng 38, 152-154 (1962)

A study of the pinch effect in wires and tubes and an application of this effect in the disintegration of fine wires.

E-162 NASILOWSKI, J., "Rozpad Drutow w Bezpiecznikoch Topikowych Przy Zwarciu," Buletyn Instytutu Elektrotechniki 14, 382-384 (1960) (Disintegration of Fuse Wires at Short Circuit)

The author uses the unduloid idea to study fuse breaking. He concludes the phenomenon is random and follows a Gaussian distribution. Number of diversions depends on wire diameter and purity, less for pure wires. Deviation from mean is also less for pure wires.

F-5 NELSON, L. S., and KUEBLER, N. A., "Nonelectrical Explosion of Metals Induced Thermally with Flash Lamps," Rev. Sci. Instr. 34, 806-808 (1963)

Photographic comparison of E. W.'s with vaporization produced by thermal radiation. The time interval is very different — 160 to several thousand μsec for the flash heating compared with a few μsec for E. W.

E-163 NIPHER, F. E., "Matter in Its Electrically Explosive State," Proc. Am. Phil. Soc. 52, 283-286 (1913)

The author investigates the effect of sending "positive" and "negative" charges through a wire. Negative charges have a greater effect. Cordenser consisted of Leyden jar.

E-164 O'DAY, M., CHACE, W. G., and CULLINGTON, E. H., "Recent Experiments on Exploding Wires and High Density Plasmas," Terzo Congresso Internazionale sui Fenomini d'Ionizzazione nei Gas (Third International Congress on Ionization Phenomena in Gases) Venice, p. 784-807 (1957)

Description of various phenomena resulting from wire explosions, pinch effect, electric gun effect, high temperatures, intense light flash. Explosion of hollow conducting cylinders. Appendices give theory of E. W. P. behavior.

S-5 O'KEEFE, J. D., and SCULLY, C. N., "Axial Flow from a Radially Confined Electrically Exploded Cylinder," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 211-222

E-165 OKTAY, E., "Effect of Wire Cross Section on the First Pulse of an Exploding Wire," Rev. Sci. Instr. 36, 1327-1328 (1965)

For his apparatus the author reports a critical voltage applied to the capacitors results in an "ideal", i. e., no restrike trace. He further reports that the critical voltage is directly proportional to wire cross section and is independent of wire length for Cu, Ag, Pt. He also points out that therefore $E_o/_m \propto R_e . E_o$ is stored energy, m = mass, R = room temp. resistance of wire.

E-166 O'ROURKE, R. C., SCHERRER, V. E., and DOBBIE, C. B., "Production of Strong Cylindrical Shock Waves by Exploding Wires," Bull. Am. Phys. Soc. 2, 47 (1957)

Produced ingoing and outgoing shocks. Measured radii vs. time, spectral luminosity vs. time. Strip film camera used.

M-17 OSHIMA, K., "Blast Waves Produced by Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 159-174

M-18 OSHIMA, K., "Blast Waves Produced by Exploding Wire," Aeronautical Res. Inst., Univ. of Tokyo 26, Report 358 (1960)

E-167 PATERSON, J. E., MURRAY, T. P., and GRIMES, W. F., "Investigations of the Use of an Exploding Wire as a Spectrographic Source," Research Report - Jones and Laughlin Steel Corp., Proj. 633, T-4 (Jan 1956)

An investigation of the feasibility of using an E. W. P. as a spectrographic source for analysis of elements such as C, S, P.

E-168 PEREGUD, B. P., and ABRAMOVA, K. B., "Experimental Study of Electrical Explosion," Dokl. Akad. Nauk SSSR 157, 837-840 (1964), Trans. in Soviet Physics-Doklady 9, 665-667 (1965)

A study of the relation between initial voltage and radiated energy. Rather slow 400 μF bank (6 kc), voltages from 800 V to 2.5 kV. In general the authors find total energy insufficient for vaporization.

E-169 PORTER, H. L., "The Electric Fusion of Fine Wires," Armament Research Establishment, Report 1/53 (1953) Ministry of Supply, Adelphi (London) w:c. 2

An exhaustive study of the fusion of fine wires at an energy level where they do not explode.

R-8 PREINING, O., "Laboratoriumsmässige Herstellung von hohen Temperaturen (bis 55,000°)," Osterreichische Chemiker-Zeitung 55, 67-72 (1954) (Production of High Temperatures (up to 55,000°) in the laboratory)

E-170 PROTOPOPOV, N. A., and KUL'GAVCHUK, V. M., "Mechanism for Interruption of Current Flow and Production of Shock Waves in a Metal Heated by High-Density Current Pulses," Zh. Tech. Fiz. (USSR) 31, 557-564 (1961) Trans. in Soviet Physics - Technical Physics 6, 399-404 (1961)

An investigation of the mechanism by which the metal is heated and the relations of this mechanism to other effects such as the interruption in current flow, shock waves, and burst of optical radiation. The authors propose that the metal vaporizes from the surface inward by a rarefaction wave, hence the speed of sound in the metal is one important factor.

J-14 PUGH, E. M., HEINE-GELDERN, R. V., FONER, S., and MUTSCHLER, E. C., "Kerr Cell Photography of High Speed Phenomena," J. Appl. Phys. 22, 487-493 (1951)

E-171 RABINOWITZ, M., "Vacuum Calorimetry in Exploding Wire Studies," Vacuum 12, 217-220 (1962)

Energy of E. W. explosion was measured by a calorimeter consisting of an Al foil (0.02 in.) cylinder with low energy equivalent (115 J/°C) placed coaxially around the wire. Temperature was measured with three thermisters. The results were compared with electrical energy measurements and were consistently less. A metal deposit formed on the calorimeter each time and had a characteristic pattern. The condenser stored 3 kJ for a 2 inch No. 28 Cu wire. A crowbar gap prevented any restrike, and in some cases was actually fired to divert energy from the explosion.

E-172 REITHEL, R. J., and BLACKBURN, J. H., "A Hydrodynamic Explanation for the Anomalous Resistance of Exploding Wires," In Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 21-31

Suggests that "inertial confinement" may cause the anomalous behavior because it reduces expansion. Increase in resistance is very largely dependent on expansion (density). Experiments with gold wire bear out the prediction above.

E-173 REITHEL, R. J., BLACKBURN, J. H., SEAY, G. E., and SKOLNICK, S., "The Current Pause in an Exploding Wire," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959), p. 19-32

Data obtained suggested different mechanisms for explosions in the cases where dwell and where no dwell occurred. In case of dwell, the current appeared to be carried by the unvaporized wire material during the first pulse, and after the pause, by the vaporized wire material. In no dwell case, breakdown occurred in the air around the wire vapor after which the current path transferred to the metal vapor.

E-174 RICHARDSON, W. H., "Exploding Wire Phenomena" (Bibliography), Sandia Corp. SCR-53 (Nov 1958)

Bibliography of 273 references. Not annotated. Not classified nor subject indexed. Arranged alphabetically by authors, thru April 1958.

F-7 RIPOCHE, J., "Générateur de Flashes Fonctionnant par Explosion de Fils Métalliques," J. phys. radium 22, 48A-52A (1961) (Exploding Wire Light Flash Generator)

M-19 RODERS, H., "Ein Stosswellenrohr mit Aufheizung der Hochdruchfüllung durch eine starke Kondensatorentladung," (A Shock Tube with Heating of the High Pressure Chamber by Means of Powerful Capacitor Discharge), in Forschungsbericht K 66-27, Bunderministerium für wissenschaftliche Forschung (Juli 1966) (Research Report K66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

E-175 ROSE, G. S., "Wire Explosions in Air and in Vacuo," J. Appl. Phys. 33, 1604-1606 (1962)

The author finds a very short dwell in vacuum explosion and postulates that dwell is caused by a rarefaction wave. Also, says the author, the wire size goes thru a critical diameter where the shock changes from strong enough to produce an almost immediate restrike to weak enough to allow an appreciable dwell.

W-4 ROSEBROCK, T. L., "Study of Plasma Mass-Velocity Distribution in a Pulsed Electromagnetic Accelerator," Allison Division, General Motors Corp., EDR 2736 (Aug 1962)

P-17 ROSEN, B., "Spectra of Diatomic Oxides by the Method of Exploded Wires," Nature 156, 570-571 (1945)

B-5 ROTHSTEIN, J., "The Arc Spot as a Steady-State Exploding Wire Phenomenon," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 115-123

R-10 ROUSE, C. A., "Lower-Upper Bounds of Temperatures for Wires Exploded in a Vacuum," Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press (1962) p. 33-35

E-176 ROUSE, C. A., "Theoretical Calculations of Exploding Wire Phenomenon," Univ. of California Lawrence Radiation Laboratory, UCRL-5684-T (1959)

A theoretical study of the hydrodynamic flow in E. W. considering a time-dependent energy deposition $(2\ E_o/\tau)\ \sin^2\ (\pi t/\tau)$. Equation of state used was that calculated from solution of Saha's Equation. Results are reported in the form of graphs of R^2 vs t and R vs t for contact surface and second shock. Results agree well with experiment.

M-20 ROUSE, C. A., "Theoretical Analysis of the Hydrodynamic Flow in Exploding Wire Phenomena," U. of Cal. (Livermore)-UCRL-5519-T (1959)

M-21 ROUSE, C. A., "Theoretical Analysis of the Hydrodynamic Flow in Exploding Wire Phenomena," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 227-263

E-177 RUEBSAMEN, W. C., SHON, F. J., and CHRISNEY, J. B., "Chemical Reaction Between Water and Rapidly Heated Metals," North American Aviation NAA SR-197 (Oct 1952)

Wire and foil were heated by condenser discharge under water to determine extent of explosive chemical reaction between the metal and water. Extent of chemical reaction determined by volume of H_2 formed and loss in weight of the metal U, Zn, Al, Ni and a few alloys of Al were investigated. Ni showed the least action. No metals reacted violently unless they were "dispersed" in the water (i. e., exploded under water).

E-178 RUTHERFORD, E., "Disintegration of Elements," Nature 109, 418 (1922)

The author's comments on Wendt and Irion's experiment.

E-179 SAKURAI, A., and TAKAO, T., "Effect of Applied Axial Magnetic Field on the Exploding Wire Phenomenon," in Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 247-256

Utilizing the simplicity of the interaction of an axial magnetic field with an exploding wire, we consider the effect of an applied magnetic field for an understanding of the phenomenon. An analysis to estimate the effect is performed under the assumption of small electrical conductivity. Experiments were conducted by exploding fine wire, of about 0. 1 mm diameter, between two magnetic pole pieces, about 2000 and 5000 G. The shock wave detected shows a decreased velocity in the magnetic field. A difference in the oscillogram of the discharge current is also noted at the "pause" period.

M-22 SAKURAI, A., "On the Propagation of Cylindrical Shock Waves," Exploding Wires. Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 264-270

E-180 SAWYER, R. A., and BECKER, A. L., "On the Explosion Spectra of the Alkaline Earth Metals," Phys. Rev. 21, 373 (1923)

Report of work on explosion of asbestos fibres soaked in solutions of salts.

E-181 SAWYER, R. A., and BECKER, A. L., "Explosion Spectra of Alkaline Earth Metals," Astrophys. J. 57, 98-113 (1923)

By exploding asbestos threads soaked in a solution of various salts, explosion spectra of alkaline earth metals were studied.

P-18 SAWYER, R. A., and BECKER, A. L., "The Production of Enhanced Line Spectra by a New Method," Science 54, 305-306 (1921)

E-182 SCHAAFS, W., "Beobachtungen an elektrischen Drahtexplosionen," Z. angew. Physik 11, 63-65 (1959) (Observations on Wire Explosions)

Description of an apparatus for flash X-rays. Drawings of some radiographs of E. W.'s. No actual prints.

X-33 SCHERRER, V. E., "An Exploding Wire Hypervelocity Projector," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 235-244

E-183 SCHERRER, V. E., "The NRL — AFSWP Exploded Wire Research Program," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 118-134

A theoretical justification for a program to produce super-high temperatures by E. W.'s and a description of the water condenser used to get less than microsecond discharges of 15 kJ into 3 mil wires.

E-184 SEYKORA, E. J., "Magnetic Mirror Confinement of Exploding Wire Plasma," Nature 191, 995-996 (1961)

Wire and mirror coil are placed in series and actuated with a 1.7 μF bank at 22 KV with 4 μsec rise time. Mirror coil was 8 turns 0.5 cm Cu with wire on the axis. All experiments in air at 1 atm. Wire was 3 mil dia. Observed with a streak camera the plasma does not expand at restrike. Longitudinal striations are observed.

R-12 SHERK, P. M., "Temperatures of Plasmas Produced by Exploding Wires under Water," Phys. Fluids 7, 913-915 (1964)

E-185 SINGER, G. J., and CROSSE, A., "An Account of Some Electrical Experiments by M. DeNelis, of Malines in the Netherlands, with an Extension of Them," Phil. Mag. 46, 161-166 (1815) and ibid 46, 259-264 (1815)

An historic paper on E. W. P. The authors were interested in the explosive force.

E-186 SLOBODKIN, L., "The Space Ship Under the Apple Tree," Macmillian Co. (1952) also special E. M. Hale and Co., Eau Claire, Wisconsin

On page 30 of this children's science fiction book the secret power is ascribed to an exploding wire made of Zurianomatichrome. Thus E. W.'s have really made the apex with their inclusion in science fiction.

E-187 SMITH, S., "A Study of Electrically Exploded Wires, Rotating Mirror Spectrograph," Astrophys. J. 61, 186-203 (1925)

A rotating mirror camera was used to observe continuous spectra with absorption lines.

E-188 SMITH, S., "Note on Electrically Exploded Wires in High Vacuum," Proc. Natl. Acad. Sci. U.S. 10, 4-5 (1924)

Repeated Wendt and Irion's experiment exploding wire in vacuum and looking for helium. None was found.

E-189 SOBOLEV, N. N., "Investigation of the Electrical Fusion of Thin Wires," Zhur. Eksp. i Teoret. Fiz. 17, 986-997 (1947)

Explosion of Cu and W wires was studied by various optical means. A discharge was observed around the W wire prior to its burst. Cu wire attains a black body temperature of 30,000°K.

P-19 SPONER, H., "Über Spektren elektrisch zerstäubter Drähte," Naturwissenschaften 12, 619-620 (1924) (The Spectra of Electrically Dispersed Wires)

E-190 STAMBLER, I., "Exploding Wires, Likely to Find Many Uses," Space/Aeronautics, 48-51 (Sept 1960)

Uses mentioned are: E. B. W., explosive forming, E. W. "Welding," producing hypervelocities, shock wave generation, propulsion, intense light sources, optical radar, photochemical reactions, pumping lasers high temperatures, soft X-rays.

The article contains also a brief description of one research project.

E-191 STARR, W. L., "Impulse from an Exploding Wire Plasma Accelerator," J. Appl. Phys. 30, 594-595 (1959)

Wires were exploded in vacuum in a T-shaped tube with a back strap. Impulse was measured with a ballistic pendulum. For wires from 2-8 mil dia. the impulse is 1000 dyne sec when exploded with 30 kV from 1.1 μF capacitor. Velocities of 8×10^6 cm/sec were recorded with image converter streak camera. Some estimates of energy utilization were made.

E-192 STARR, W. L., and NAFF, J. T., "Acceleration of Metal Derived Plasmas," Lockheed Tech. Memo LMSD-288240 (Dec 1959)

Plasmas were derived from exploding wires, sputtering, arc erosion, and accelerated in "T", rectangular, and coaxial geometry. Impulse was measured by accelerated pendulum. Photos of luminous plasma fronts were made. With E. W. there was no measureable dependence of plasma front velocity on wire size. This was true for Pt, Cu, W, Nichrome, Ag and Al.

X-37 STARR, W. L., "Exploding Wire Plasma Accelerator," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 365-373

E-193 STEVENSON, M. J., REUTER, W., BRASLAU, N., SOROKIN, P. P., and LANDON, A. J., "Spectral Characteristics of Exploding Wires for Optical Maser Excitation," J. Appl. Phys. 34, 500-509 (1963)

Integrated spectra of wires, Cu, Ag, Au, Nb, W, Ta, Ma, Pt, Ir, Fe, Ti, Al, and a few alloys, as well as carbon rods coated with salts were obtained. Explosions were carried out in air and vacuum. For pumping lasers the blackbody continuum is very desirable particularly as it is in U-V. Vacuum explosions give this type of output.

E-194 STRONG, C. L., "How to Make Extremely Energetic Sparks for High-Speed Photography and Other Purposes," Sci. Am., 148-160 (Nov 1957)

One of the "Amateur Scientist" series. Directions for making an underwater E. W. setup, and some suggested experiments. Also description of a simple Kerr Cell.

E-195 SUITS, C. G., "Notes on High-Intensity Sound Waves," General Electric Review 39, 430-434 (1936)

The author uses Schlieren methods and other optical methods to study sound waves produced by E. W.'s. The sound waves are used to extinguish arcs and flames.

Q-11 TATIBANA, F., "Triggering Electrical Breakdown in High Vacuum by Wire Explosion," J. Appl. Phys. (Japan) 30, 71-72 (1961)

P-20 TEEPLE, L. R., Jr., "Application of a Time Resolving Spectrograph System," VI Internat. Congress on High-Speed Photog. (The Hague) (1963) p. 605-612

E-196 THOMAS, R. J., and HEARST, J. R., "An Electronic Scheme for Measurement of Exploding Wire Energy," Lawrence Rad. Lab. (Livermore) UCRL-14170 (1965)

Measurements of energy were made from E = ∫ eidt using a compensated voltage divider based on the Moses and Korneff method. The results were compared with optical measurements and agreed within 25%. Explosions were made under water and in air.

E-197 THOMPSON, J. J., "Analysis by Positive Rays of the Heavier Constituents of the Atmosphere, of the Gases in a Vessel in which Radium Chloride had been Stored for Thirteen Years and of the Gases Given Off by Deflagrated Metals," Proc. Roy. Soc. (London) 101A, 290-299 (1922)

Among other things analyzed by positive ray methods the author analyzes "the gases given off when fine wires of tungsten or copper are deflagrated by powerful electric currents."

E-198 TIEMANN, W., "Vergleich von Theorie und Experiment bei der Drahtexplosion," (Comparison of Theory and Experiment in Wire Explosions), in Forschungsbericht K66-27, Bundesministerium für Wissenschaftliche Forschung (Juli 1966) (Research Report K66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

Experimental investigation of dwell time and reignition phenomena of E.W., and comparison with the theory of detonation.

S-7 TIMOFEEVA, G. G., "Pinch Effect and Breaking of the Arc in the Constriction," Zh. Techn. Fiz. 27, 2669-2671 (1957)(trans. in Soviet Physics-Tech. Phys. 2, 2480-2481) (1957)

M-24 TODD, J., Jr., "A Photographic Study of Sources of Spherical Shock Waves," SCTM-242-54(51) (Nov 1954)

E-199 TOEPLER, M., "Beobachtung von Metalldampfschichtung bei elektrischer Drahtzerstäubung," Ann. Physik 65, 873-876 (1898) (Observation of Metal Vapor Coating by Electrical Vaporization of Wires)

An investigation of the vapor deposit produced on glass plates placed 2 or 3 mm from an exploding wire.

P-21 TRICHE, C., "Étude Spectrographic de l'Émission des Fils Explosés," (Spectrographic Study of Emission from Exploding Wires), J. Chemie Phys. 62, 291-296 (1965)

H-8 TSAI, D. H., and PARK, J. H., "Calorimetric Calibration of the Electrical Energy Measurement in an Exploding Wire Experiment," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 97-107

E-200 TUCKER, T. J., "Behavior of Exploding Gold Wires," J. Appl. Phys. 32, 1894-1900 (1961)

A study of resistance-current density behavior. Relations of current, action and resistance. Kerr Cell photographs show evidence of arcing around the wire at high current densities.

E-201 TUCKER, T. J., "Possible Explanation of the Current Density-Dependent Resistivity of Exploding Wires," J. Appl. Phys. 30, 1841-1842 (1959)

The author relates the dependence of resistivity of Au wires on energy, to arcs through the surrounding air. These arcs are indicated by Kerr Cell photographs of E. W.'s. Current densities 10^7 and 10^8 A/cm^2

E-202 TUCKER, T. J., and NEILSON, F. W., "The Electrical Behavior of Exploding Wires. A Survey of Various Materials," Sandia Corp. SCTM 334-59 (51), revised (1959)

A survey of various metals exploded by a cable discharge system. Data presented as graphs of inertia-resistance and energy-resistance.

E-203 TUCKER, T. J., and NEILSON, F. W., "The Electrical Behavior of Fine Wires Exploded by a Coaxial Cable Discharge System," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 73-82

By storing energy in a long section of coaxial cable, wires are exploded with a 3 μsec, 600 amp square pulse of energy. Finds energy-to-burst dependent on current density. Voltage and current easily measured because of the completely coaxial arrangement.

E-204 TURNER, B. R., "A Study of Exploding Wires," Cal. Tech. Thesis (1960)

Study of E. W.'s by comparing Rouse's shock calculations and observations. Time integrated spectral energy density was determined from 2300 A to 5500 Å for Fe wire, I and E were measured and Kerr cell photos were made for Fe, Ag, Cu, W, Al. Some photos were made of explosions in vacuum

E-205 VANYUKOV, M. P., and ISAENKO, V. I., "Investigation of Light Produced by Exploding Wires," Zh. Techn. Fiz. 32, 197-201 (1962) Trans. in Soviet Physics-Tech. Phys. 7, 138-142 (1962)

Optical emission and development of the gas cloud from E. W. 's examined with image-converter. A brief discussion of the photos re light development, shock waves, and vapor cloud propagation. A comparison between spark discharge and E. W. 's. Comparison of results for different lengths and diameters of wires.

E-206 VAUDET, G., "Étude et Emploi d'une Source Lumineuse de Grande Brilliance," Ann. Phys. 9, 645-722 (1938) (The Study and Use of a Light Source of Great Brilliance)

The author makes a rather thorough study of E. W. P. Included are considerations of duration, temperature, and spectroscopy. A carefully constructed switch is described but found experimentally disappointing. A mathematical analysis of an oscillating circuit with variable resistance is attempted. Suggested uses for E. W. P. are given.

P-22 VAUDET, G., and SERVANT, R., "Spectres de fils explosés dan l'ultraviolet Lointain et la region Schumann," Compt. Rend 201, 195-197 (1935) (Spectra of Exploded Wires in the Far Ultraviolet and Schumann Regions)

E-207 VITKOVITSKY, I. M., "X-ray Emission from Exploding Wires," Phys. Fluids 7, 612-613 (1964)

Hollow Al tubes were exploded-imploded in 10^{-8} sec at 400 kV. Soft X-rays were observed to come from center of the tube along the entire length. The photons have energy of only a few kV. Curves of computed vs observed temperatures are given.

T-6 VITKOVITSKY, I. M., BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., and SHIPMAN, J. D., Jr., "Exploding Wires as a Source of X-rays," Exploding Wires. Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 87-96

X-38 WAGNER, H. J. and BOULGER, F. W., "High Velocity Metalworking Processes Based on the Sudden Release of Electrical Energy," Batelle Memorial Institute, Defense Metals Information Center, DMIC Memo 70 (Oct 1960)

E-208 WEBB, F. H., Jr., "Study of Electrically Exploded Wire Materials," ESO Report 210-QL-7 (May 1960), Electro Optical Systems, Inc. Quarterly Progress Report

Discussion of theoretical scaling by Ohm's Law - and direct resistivity - temperature relation. An attempt to find an energy density-resistivity relation.

E-209 WEBB, F. H., Jr., "Study of Electrically Exploded Wire Materials," Electro-Optical Systems Report 210- QL-4 (1959)

A study, mostly of Al wires, of 1 mil X .290" wires with millimicrosecond instrumentation - I, E, energy, and Kerr Cell photos. A theory of the resistance behavior is put forth balancing vaporization and pinch effects. Radiation entrapment is considered. Radiation is less important in the millimicrosecond region than in the microsecond. Some discussion of a rarefaction wave similar to that proposed by Müller.

E-210 WEBB, F. H., Jr., BINGHAM, H. M., and TOLLESTRUP, A. V., "High-Energy Densities before Dwell in Electrically Exploded Wires," Phys. Fluids 3, 318-319 (1960)

A study of maximum energy in the wire before transplosion (up to 10 ev/atom). di/dt = 3×10^{11} amp/sec current rise. Report inertial pressures of $\sim 10^5$ atm where pinch pressure is $\sim 10^3$ atm. Current densities were $\sim 4 \times 10^8$ amp/cm^2. Luminous zone moving at 9 km/sec. Very rapid heating 17 nanoseconds to vaporization of 1 mil approximately 1/4" long. Ag, Cu and Al wires. Observed dwell, current during dwell. Expansion of luminous zone slows materially at restrike. Some Kerr Cell photos.

E-211 WEBB, F. H., Jr., CHASE, N., ERNSTENE, M., and TOLLESTRUP, A. V., "Submicrosecond Wire Explosion Studies at Electro-Optical Systems, Inc.," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959) p. 33-58

Electrical and optical studies of small (1 mil X 0.290") wires of Al, Cu, Ag, Au, Ni and W exploded with very fast 2000$\mu\mu$f system charged to 10 or 20 kv. Partly triggered gap and partly thyratron controlled.

E-212 WEBB, F. H., Jr., HILTON, H. H., LEVINE, P. H., and TOLLESTRUP, A. V., "The Electrical and Optical Properties of Rapidly Exploded Wires," Exploding Wires, Vol. II, Chace and Moore, (eds), Plenum Press, New York (1962) p. 37-75

A study of small wires at very high explosion rates. (Times were $<10^{-7}$ sec.) Study by oscillograms, Kerr cell photos, and light measurements.

E-213 WEBB, F. H., Jr., HILTON, H. H.. LEVINE, P. H., and TOLLESTRUP, A. V., "Exploring the Nature of Bridgewire Explosions," Space/Aeronautics 75-80 (Aug 1962)

A discussion behavior of 0.5 mil X 0.29 to 0.50 in Cu, Ag, Al, Au, Sn, Zn, Cd, W, Mo, Pt, Ni, Fe, Ti wires in a bank of 0.02 μF and 10-20 KV. The results are examined on basis of energy input and classical theories of evaporation, expansion and shock waves. Data is presented in form of graphs (13).

E-214 WENDT, G. L., and IRION, G. E., "Experimental Attempts to Decompose Tungsten at High Temperatures," J. Am. Chem. Soc. 44, 1887-1894 (1922)

Explosion of tungsten wires produce a gas which gives a helium spectrum. Authors postulated transmutation.

E-215 WILSON, R., "The Infrared Spectral Radiant Intensity of Exploding Wires," U.S.N. Ord. Test Stn. NOTS TP 2697 (1961)

One inch × 0.004 in. diameter stainless steel wires exploded with 667 μf condenser at 300 V. IR output was measured on a filter radiometer using optical filters and a lead selenide detector cooled with liquid H_2. Output of detector recorded along with a time trace, a photomultiplier signal and a calibrating trace from a 1000°C black-body source. Region covered is 2-6 μ in 0.5 μ steps. Concludes temps in 1700-1800°C at first peak 2500°C at secondary peak, 3.5 millisec later.

E-216 WINKLER, R., BERTHOLDI, W., and KRESSNER, H., "Zur Klassifikation von Drahtexplosionen," (The Classification of Wire Explosions), Monatsh, Deut. Akad. Wiss., Berlin 7, 527-541 (1965)

The authors propose a system based on energy and the "action integral." They propose Heating-Melting, where action integral is not constant and explosion where action integral is constant. They then divide explosions into: wire explosion with current interruption, wire explosion with dwell, wire explosion without dwell. Equations are set up between voltages and breakdown potentials.

E-217 WRANA, J., "Vorgänge beim Schmelzen und Verdampfen von Drähten mit sehr hochen Stromdichten," Phys. Ber. 21, 522 (1940) (Processes in the Melting and Vaporization of Wires with Very High Current Densities)

Abstract of E-218

E-218 WRANA, J., "Vorgänge beim Schmelzen und Verdampfen von Drähten mit sehr hochen Stromdichten," Arch. Electrotech. 33, 656-672 (1939) (Processes in the Melting and Vaporization of Wires with Very High Current Densities)

A study of fuses under high surge-currents. Believes interruption of current due to practically zero conductivity of metal vapor near the boiling point. Some study of inductive over-voltage and the effects of enclosing the wire.

E-219 WRANA, J., "Vorgänge in Sicherungen bei elektrischer Stossbelastung," Electrotech. Z. 59, 11-13 (1938) (Processes in Fuses Subjected to Surge Currents)

The author investigates the mechanical and electrical behavior of several types of high voltage fuses when subjected to surge currents. He finds it necessary to classify action according to energy of pulse.

Section E

A-21 WURSTER, W. H., "High Speed Shutter for Spectrographs," Rev. Sci. Instr. 28, 1093-1094 (1957)

J-18 ZAREM, A. M., MARSHALL, F. R., and HAUSER, S. M., "Millimicrosecond Kerr Cell Camera Shutter," Rev. Sci. Instr. 29, 1041-1044 (1958)

E-220 ZAREM, A. M., MARSHALL, F. R., and POOLE, F. L., "Transient Electrical Discharges: Disintegration of Small Wires," Phys. Rev. 72, 158 (1947)

Studied explosions of platinum wire. Current and voltage oscillograms, Kerr cell photographs.

P-23 ZERNOW, L., and HAUVER, G. E., "High Speed Cine-Microscopy and Space-Time Resolved Spectroscopy," in High Speed Photography, R. B. Collins (ed, Butterworth, London (1957) p. 305-314

J-19 ZERNOW, L., and HAUVER, G., "Cine-Microscopy of Sparks, Exploding Wires, and Fracture at Framing Rates 10^6/second," Phys. Rev. 98, 1551 (1955)

J-21 ZERNOW, L., and WOFFINDEN, G., "The Cinemicroscopic Observation of Exploding Wires," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959) p. 170-185

E-221 ZERNOW, L., WOFFINDEN, G., and KREYENKAGEN, K. N., "High Speed Cinemicrography of Electrically Exploded Tungsten and Molybdenum Wires," Photo Science and Engineering 4, p. 31-36 (1960)

Similar to the work reported in E. W. Vol. I and Soc. Photo Scientists and Engineers meeting paper.

EXPLODING BRIDGE WIRE – Section Eb

Eb-1 BELAJEV, A. F., "The Production of Detonation in Explosives under the Action of a Thermal Impulse," Comptes Rendus (Doklady) Acad. Sci. USSR XVIII, 267-269 (1938) (In English)

Thermal pulse produced by exploding Pt wire was used to study relation of energy supplied to detonation in liquid explosives (NCl_3 and nitrogylcerine). The author proceeds on the assumption that heat alone produces the detonation, pressure merely prevents evaporation with attendant absorption of heat. Shock waves are not mentioned.

Eb-2 BETTS, R. E., "Development and Functional Characteristics of the XM-6 and XM-8 Squibs," Proc. Elec. Initiator Symposium, Philadelphia, (1963) The Franklin Institute

Discussion of the characteristics of these two EBW ignition devices and the considerations which led to their design.

Eb-3 BLACKBURN, J. H., and REITHEL, R. J., "Exploding Wire Detonators: Sweeping-Image Photographs of Exploding Bridgewire Initiation of PETN," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964), p. 153-173

The initiation of detonation in PETN by an exploding wire is studied by means of a sweeping-image camera. Photographs taken through the transparent head of a detonator reveal that the shock wave generated by the exploding wire accelerates until it becomes the detonation wave in the explosive. The rapidity of this evolution is increased by increasing the specific surface of the granular explosive and by increasing the intensity of the bridgewire explosion. To study initiation, PETN was pressed into a transparent container against a bridgewire. Photographs of the initiation to detonation of the explosive were taken both by the self-light of the process and by external illumination from a second exploding wire. Experiments show that the rear-view photographs are not distorted nor is the PETN disturbed by shock waves in the material of the transparent container.

Eb-4 DiPERSIS, R., "Exploding Wire and Spark Gap Central Initiator for High Explosives," BRL Memo Report No. 851 (Oct 1954) AD 59600

Pentolite is initiated with a booster of PETN which is in turn initiated with either an EBW or a spark gap. A nearly spherical shock wave may be so produced.

Eb-5 KNUDSON, L. I., and FORBES, R. E., "Design Concepts for an Exploding Bridge Wire Electronic Ignition System," Elect. Eng. 81, 523-528 (1962)

A brief description of an EBW system with some details on design requirements.

Eb-6 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires: VIII Survey to Determine Explosives Capable of Initiation at Moderate Voltage Levels," Nav. Ord. Lab. NOLTR 65-127 (1966)

The explosives: PETN, TNETB, RDX, HNAB, DINA, BTNES, HNH, and HMX can be initiated high order by a 2-mil diameter gold wire exploded by a 1-microfarad capacitor charged to 4000 volts. These explosives are rated as fairly sensitive secondary explosives by the impact test. PETN exhibits the fastest build-up to detonation of the explosives that initiated.

Eb-7 LEOPOLD, H. S., "Effect of Energy Termination on the Initiation of PETN by Exploding Wires," NOLTR 65-56 (1965)

Artificial termination of the capacitor discharge pulse to gold and platinum bridgewires shows that the arc phase is largely unnecessary for effecting detonation in PETN. The time of energy termination is dependent upon when the PETN reaction becomes self propagating. Two modes of initiation by exploding wires are suggested by the experiments: Pure shock, and the combination of shock and thermal energy inputs.

Eb-8 LEOPOLD, H. S.,"Initiation of Explosives by Exploding Wires," NOLTR-65-1 (1965)

Silver, copper, and iron wires were investigated as possible bridgewire materials. The wires were exploded by a 1-microfarad capacitor charged to 2,000 volts. Peak power input to the bridgewire is relatively more important than the energy required for vaporization. Low boiling point, low heat of vaporization metals such as silver and copper permit greater energy transfer to an explosive than high boiling point, high heat of vaporization metals such as iron.

Eb-9 LEOPOLD, H. S., "Effect of Wire Material on the Initiation of PETN by Exploding Wires," NOLTR 64-146 (1964)

Aluminum, gold, platinum, and tungsten wires were investigated to determine the effect of the wire material on the initiation of PETN by exploding wires. The results indicate that favorable wire materials are those into which energy is deposited at a rapid rate. They also have low boiling points and low heats of vaporization.

Eb-10 LEOPOLD, H. S., "Effect of Wire Diameter on the Initiation of PETN by Exploding Wires," NOLTR 64-2 (1964)

The effect of wire diameter on the initiation of PETN by exploding platinum wires was investigated. The diameter of the wire can be chosen so as to favor time reproducibility of explosion, reliability of effecting detonation, or vigor of the bridgewire output.

Eb-11 LEOPOLD, H. S., "Effect of Wire Length on the Initiation of PETN by Exploding Wires, NOLTR 64-61 (1964)

The effect of wire length on the initiation of PETN by exploding platinum wires was investigated. There is an optimum wire length apparently governed by the energy density deposited in the wire and a minimum critical volume of explosive which must be initiated.

Eb-12 LEOPOLD, H. S., "Effect of Bridgewire Parameters on Explosive Initiation," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 125-152

The direct initiation of secondary explosives by exploding wires is finding increasing application in the missile and space vehicle fields. Experimental results are given showing the effect of wire diameter, length, and material on the initiation of PETN by a wire subjected to the rapid discharge of a 1 μF capacitor charged to 2000 V. The diameter of the wire can be chosen so as to favor time reproducibility of explosion, reliability of effecting detonation, or vigor of the bridgewire output. For effecting detonation there is an optimum length for each wire material apparently governed by the energy density in the wire and a minimum critical volume of explosive which must be initiated. Favorable wire materials are those into which the energy can be deposited at a high rate and which also possess low boiling points and heats of vaporization.

Eb-13 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires," U.S.N. Ord. Lab. NOLTR 63-244 (1964)

The effects of circuit resistance and bridgewire length on the initiation of PETN by exploding 1 mil diameter platinum wires were investigated. A 1 μF capacitor charged to 2000 V was used as the energy source. Increasing circuit resistance reduces the current density and the energy input to the wire lowering the probability of producing detonation in PETN. The importance of keeping the extraneous circuit resistance to an absolute minimum is shown.

Eb-14 LEOPOLD, H. S., "Bridgewire Diameter Design Considerations for an EBW Initiator," Proc. Elect. Initiator Symposium, Philadelphia (1963) The Franklin Institute p. 23-1 to 23-13.

Relation of wire diameter to vigor of explosion was investigated. Wire with most vigorous explosion is not always most efficient in effecting detonation. Diameter can be chosen to favor reproducibility, reliability, or vigor.

Eb-15 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires," U.S. Nav. Ord. Lab. NOLTR 63-159 (1963)

Effects of circuit inductance and bridgewire length on initiation of PETN by exploding platinum wires were investigated, using capacitor discharge as energy source. Oscillograms of current and voltage, and smear camera records were used to interpret wire explosion and initiation. Increasing circuit inductance lowers the probability of detonation in PETN by an exploding wire. For effective initiation, bridgewire length should be chosen to eliminate current dwell.

Eb-16 LEOPOLD, H. S., "Photographic Studies of Growth of Explosion," U.S. Nav. Ord. Lab. NOLTR 62-86 (1962)

Rotating mirror smear camera technique is described for observing growth of explosion in silver azide, lead azide, lead styphnate, and PETN when initiated by nichrome wire. Energy was delivered by discharging through wire a 1 microfarad capacitor charged to preselected potentials of 100, 500, and 2000 volts. Wire explodes at 500 and 2000 volt potentials. Time from beginning of input pulse to time of explosion was a function of potential (consequently, power and energy as well.)

Eb-17 MENICHELLI, V. J., "Reliable Exploding Bridgewire Remains to be Developed," Missiles and Rockets, 13, Dec 34-35 (1963)

Introductory discussion of reasons for, current development and remaining problems of EBW. Some discussion of military requirements.

Eb-18 MOORE, D. B., "Characteristics of a Small Insensitive PETN Electric Detonator," Proc. Elect. Initiator Symposium, Philadelphia, (1963) The Franklin Institute

Ignition is by discharge of 1/2 μF capacitor charged to 2-4 kV thru PETN-graphite mixture from a point electrode. The device is RF proof only because it is coaxial.

Eb-19 MULLER, G. M., MOORE, D. B., and BERNSTEIN, D., "Growth of Explosion in Electrically Initiated RDS," J. Appl. Phys. 32, 1065-1075 (1961)

Study of explosion in RDX from an EBW. It is shown that loading density of the HE is more important than the stored electrical energy.

Eb-20 PELPHREY, J., "Development of an Exploding Bridgewire Propellant Ignition System for Davy Crockett," Proc. Elec. Initiator Symposium, Philadelphia, (1963) The Franklin Institute

Gold Wire fired at 2200 volts (all fire 968 volts) from power pack of 4 size D flashlight cells. A 1 μF capacitor was used. PETN in the detonator was packed to ca 0.925 g/cc.

Eb-21 REYNOLDS, L. J., "High Energy EBW Firing Unit," Missiles and Space 11, 18-19 (1963)

Description of the electronic circuitry used in firing exploding bridge wires in missile service. Nothing about the wires themselves.

E-190 STAMBLER, I., "Exploding Wires Likely to Find Many Uses," Space/Aeronautics, 48-51 (Sept 1960)

Eb-22 STEPPE, A. J., and MASSEY, J. M., "Discourse on M.T.L.-I-23659 (WEP)," Proc. Elect. Initiator Symposium, Philadelphia (1963) The Franklin Institute

A discussion of the Navy minimum specification for Electric-Initiators. This includes hot wire initiators, conductive mix initiators as well as EBW's.

Eb-23 STRESAU, R. H., and HILLYER, R. M., "Exploding Bridgewire Initiation of RDX with 50 Millijoules," Proc. Elect. Initiator Symposium, Philadelphia, (1963) The Franklin Institute

A very low energy EBW system was desired for multiple ignition. Such low energy requires careful balance of loading, circuit impedance, state of aggregation of explosive and electric pulse form. A practical device is described.

Eb-24 TUCKER, T. J., "Exploding Wire Detonators: The Burst Current Criterion of Detonator Performance," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 175-184

This paper discusses EBW detonator initiation characteristics in terms of dynamic electrical requirements of the bridgewire. It is shown that one quantity, the "burst current" defined as bridgewire current at voltage maximum, can be correlated with explosive initiation independent of external system properties. It is further shown that detonator firing thresholds add explosive transmission times, when expressed as function of burst currents, can be related to detonator parameters such as bridgewire dimensions. Since burst currents are related to system properties through the action integral, $G = gA^2$ (where G is the action, g the material constant, and A the cross-sectional area of the bridgewire), it is now possible to estimate the performance of any EBW detonator and its firing system.

LIGHT – Section F

E-10 ANDERSON, J. A., "The Spectral Distribution and Opacity of Wire Explosion Vapors," Proc. Nat. Acad. Sci. U.S. 8, p. 231-232 (1922)

X-2 ANDREEV, S. I., and VANYUKOV, M. P., "Use of Electrical Explosion of Wires to Produce Ultra-short Light Flashes," Zh. Techn. Fiz. 34, 1871-1872 (1964), Trans. in Soviet Physics-Tech. Phys. 9, 1443-1444 (1965)

X-3 ANDREEV, S. I., and VANYAKOV, M. P., "Methods of Shortening Light Flash Duration and Increasing Intensity," VI Internat. Congress on High-Speed Photog. (The Hague) (1963), p. 166-172

F-1 CASSIDY, E. C., and ABRAMOWITZ, S., "Studies of Some Exploding Wire Light Sources," J. Soc. Mot. Picture and T. V. Engrs. 75, 734-737 (1966)

A study of the spectrum produced by wire explosions. Most of the analysis was of the residue produced by the explosion with times up to 1 ms after the burst. The authors discuss Al and Ti in this paper.

X-9 CHURCH, C. H., HAUN, R. D. Jr., OSIAL, T. A., and SOMERS, E. V., "Optical Pumping of Lasers Using Exploding Wires," Appl. Optics 2, 451-452 (1963)

E-73 CONN, W. M., "The Use of 'Exploding Wires' as a Light Source of Very High Intensity and Short Duration," J. Opt. Soc. Am. 41, p. 445-449 (1951)

E-75 CONN, W. M., "Note on the Polarization of Light Emitted by Electrically Exploded Wires," Phys. Rev. 58, 50-51 (1940)

E-78 DAY, P. B., "The Radiant Intensity of Electrically Exploded Wires," J. Opt. Soc. Am. 43, 817 (1953)

E-87 ESCHENBACH, R. C., "Measuring Voltage in an Exploding Wire Discharge," Army Project 4A (July 1948)

F-2 FISH, C. V., and CHACE, W. G., "Uniform Light from Exploding Conductor," Rev. Sci. Instr. 37, 1401 (1966)

Description of light source from explosion of conducting plastic ribbons.

N-5 FLOWERS, J. W., "The Channel of the Spark Discharge," Phys. Rev. 64, 225-235 (1943)

D-2 GOOD, R. C., Jr., "Structural Response to Intense Electromagnetic Radiation," G. E. Space Science Lab. Report AFOSR-2483, First Annual Tech. Rept. (Feb 1962)

J-6 HEINE-GELDERN, R. V., PUGH, E. M., and FONER, S., "Kerr Cell Photography of High Speed Phenomena-Detonation and Shock Phenomena," Phys. Rev. 79, 230 (1950)

J-7 HOLTZWORTH, R. E., and HINZ, D. J., "Exploding Wire Backlighting for the Study of Detonation, Shock and Shaped Charges," Ballistics Research Lab. Rept 818 (May 1952)

X-26 KLEIN, A. F., "Some Results Using Optical Interferometry for Plasma Diagnostics," Phys. Fluids 6, 310-311 (1963)

F-3 LEWIS, M. R., and SLEATOR, D. B., "Exploding Wire Light Source for High Speed Interferometry," Ballistic Research Laboratory Memo Report 975 (Feb 1956)

Description of apparatus and measurement of light output.

J-9 LIDDIARD, T. P., and DROSD, R. D., "Exploding Wires for Light Sources in Fast Photography," U. S. Nav. Ord. Lab. Memo 10840 (1950)

X-31 MARCUS, R. A., "Application of the Exploding Wire Technique in Photochemistry," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 307-314

F-4 MEINERS, D., BORTFELDT, J., WEBER, W., WITTIG, L., "Ein Verfahren Zur Messung des Absorptionskoeffizienten in inhomogenen und instationären Plasmasäulen mit höher optischer Schichtdicke," (A Method for Measuring the Absorption Coefficients in nonhomogeneous and nonstationary plasma columns with optical density), in Forschungsbericht

K 66-27, Bundesministerium für wissenschaftliche Forschung (Juli 1966) (Research Report K 66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

Development of a photographic method to determine the absorption coefficient within nonstationary and nonhomogeneous dense plasmas of high optical densities. Use of E. W. as example of the dense plasma.

E-144 MOESTA, H., and BREWER, D., "Liquid Metal as an Exploding Wire for Repeatable Operation in Vacuum Work," Rev. Sci. Instr. 36, 1372-1373 (1965)

F-5 NELSON, L. S., and KUEBLER, N. A., "Nonelectrical Explosion of Metals Induced Thermally with Flash Lamps," Rev. Sci. Instr. 34, 806-808 (1963)

Photographic comparison of E. W.'s with vaporization produced by thermal radiation. The time interval is very different - 160 to several thousand μsec for the flash heating compared with a few μsec for E. W.

F-6 OSTER, G. K., and MARCUS, R. A., "Exploding Wire as a Light Source in Flash Photolysis," J. Chem. Phys. 27, 189-192 (1957)

Nichrome wire behaves as line source rich in ultraviolet. Light output measured by uranyl oxalate actinometry. Luminous efficiency is 10 percent. Results found highly reproducible.

F-7 RIPOCHE, J., "Générator de Flashes Fonctionnant par Explosion de Fils Métalliques," J. Phys. Radium 22, 48A-52A (1961) (Exploding Wire Light Flash Generator)

Describes apparatus and records light output as a function of time, wire material, and condenser voltage.

E-205 VANYUKOV, M. P., and ISAENKO, V. I., "Investigation of Light Produced by Exploding Wires," Zh. Techn. Fiz. 32, 197-201 (1962) Trans. in Soviet Physics-Tech. Phys. 7, 138-142 (1962)

E-220 ZAREM, A. M., MARSHALL, F. R., and POOLE, F. L., "Transient Electrical Discharges: Disintegration of Small Wires," Phys. Rev. 72, 158 (1947)

MATHEMATICS – Section G

E-9 ANDERSON, J. A., "Electrically Exploded Wires," International Critical Tables Vol. 5, p. 434 (1929) McGraw-Hill, New York.

Section G

E-13 ANDERSON, J. A., and SMITH, S., "General Characteristics of Electrically Exploded Wires," Astrophys. J. 64, 295-314 (1926)

A-1 BELLASCHI, P. L., "Heavy Surge Currents - Generation and Measurement," Trans. Am. Inst. Elec. Engrs. 53, 86-94 (1934)

E-36 BETHGE, O., "Mechanische Verformungen durch Elektrische Entladungen," Ann. Physik 8, 475-499 (1931) (Mechanical Distortions due to Electrical Discharges)

P-3 CASE, Roger, S., Jr., "Time Resolved Spectroscopy of Exploding Wires," Thesis, AFIT GSP/PH/66-2 (1966)

E-77 DAVID, E., "Physikalische Vorgänge bei elektrischen Drahtexplosionen." Z. Physik 150, 162-171 (1958) (Physical Processes in Electrical Wire Explosions)

S-1 GELDMACHER, R. C., "Recent Contributions to the Macroscopic Analysis of Conducting Electromechanical Solids," Exploding Wires Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 15-20

E-95 GOOD, R. C., Jr., "Resistance Variation of Exploding Wires," Exploding Wires, Vol. III, Plenum Press, New York, (1964) p. 23-35

When fine wires are exploded by discharging a capacitor, the circuit exhibits damped electrical oscillations as an L-R-C circuit; however, the resistance varies during the explosion which complicates the analysis. To date the resistance has been calculated either by integrating twice in succession the record of the rate of change of the current, or by the current-voltage-method. A different approach is proposed in which the circuit equation is differentiated with respect to time and then solved by a method similar to the WKB method. The method is discussed, original data provided, and values of calculated resistances obtained by the double integration method are used to indicate the validity of the solution.

E-103 HOBSON, A., and MANKA, C. K., "Premelt Variation of Current, Temperature, and Resistance in Exploding Wires," J. Appl. Phys. 37, 1897-1901 (1966)

U-6 LANGBERG, E., "Analysis of Exploding Foil Process," Avco Corp - RAD-TN-65-40 (1965)

E-132 LESNIK, A. G., "Concerning One Necessary Condition for the Vaporization of a Metal Wire by Exploding it with Current," Dokl. Akad. Nauk SSSR 17D, 1050-1061 (1966)

M-14 LIN, S., "Cylindrical Shock Waves Produced by Instantaneous Energy Release," J. Appl. Phys. 25, 54-57 (1954)

S-3 MANINGER, R. C., "Effects of Transmission Lines in Applications of Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 109-126

E-138 MANINGER, R. C., "Preburst Resistance and Temperature of Exploding Wires," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 47-64

E-206 VAUDET, G., "Étude et Emploi d'Une Source Lumineuse de Grande Brilliance," Ann. Physik 9, 645-722 (1938) (The Study and Use of a Light Source of Great Brilliance)

MEASUREMENTS – Section H

H-1 ALLIBONE, T. E., and MEEK, J. M., "The Development of the Spark Discharge," Proc. Roy. Soc. (London), A166, 97-126 (1938) ibid A169, 246-268 (1938)

Detailed study of sparks. Measurement techniques are applicable to E. W. P.

P-1 ANDERSON, J. A., "Spectral Energy-Distribution of the High-Current Vacuum Tube," Astrophys. J. 75, 394-406 (1932)

H-2 BENNETT, F. D., "Transient Skin Effects in Exploding Wire Circuits," BRL Report 1137 (August 1961)

A mathematical (Fourier transform) analysis of the coaxial shunt, flat plate condenser (and leads) and tubular condenser. Exact analytic solution not possible, but approximation shows that (1) peak current given within <1%, (2) initial slope indicated is always less than impressed slope for shunt, (3) as long as characteristic time, $\mu \sigma a^2$ is negligible compared th time of 1 oscillation, transient resistance of condenser and le .s is negligible.

E-32 BENNETT, F. D., BURDEN, H. S., and SHEAR, D. D., "Correlated Electrical and Optical Measurements of Exploding Wires," BRL Report 1133 (June 1961)

H-3 BENNETT, F. D., and MARVIN, J. W., "Current Measurement and Transient Skin Effects in Exploding Wire Circu' s," Rev. Sci. Instr. 33, 1218-1226 (1962)

Transient response of the coaxial current measuring shunt is analyzed by ˉ aplace transforms. Estimates of errors to be expected are shov .. The shunt reading is a few percent too low at

current maximum. The behavior of an ideal flat plate condenser is analyzed and it is shown that this produces negligible results on the initial conditions as long as the characteristic damping time of the transient skin effect is small compared with the ringing time.

E-39 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S.N.R.L. Prog. Report (1 Nov 61 - 1 Feb 62)

T-1 BEY, P. P., FAUST, W. R., FULPER, R., HARRINGTON, F. D., LEAVITT, G. E., SHIPMAN, J. D. and VITKOVITSKY, I. M., "Exploding Wire Studies," NRL Prog. Report (1 Aug to 1 Nov 61)

A-7 CHACE, W. G., and CULLINGTON, E. H., "Instrumentation for Studies of the Exploding Wire Phenomenon," Instr. Geophys. Res. No. 7, AFCRC-TR-57-235 (1957)

H-4 CHASE, N., HANKIN, N., and WEBB, F. H., Jr. "Instrumentation for Exploding Wire Research," Electronics, (July 1, 1960), p. 43-45

Description of equipment requirements and a qualitative statement of how current and voltage are measured, how wire explosion is photographed, and how the wire exploding circuit should be set up.

A list of uses and possible uses of E.W.'s is given.

B-1 COBINE, J. D., and BURGER, E. E., "Analysis of Electrode Phenomena in the High-Current Arc," J. Appl. Phys. 26, 895-900 (1955)

H-5 COX, J. H., and LEGG, J. W., "The Klydonograph and Its Application to Surge Investigations," Trans. Am. Inst. Elec. Engrs. 44, 857-871 (1925)

The Klydonograph, familiar to power engineers but little used by physicists. A useful photographic method of investigating high voltage pulses.

B-2 DIEKE, G. H., "Study of Variations in Light Sources as They Effect Spectroscopy," ASTM Tech. Pub. No. 76, 37 (1946)

E-85 EISELT, B., "Über den Ablauf von Draht Explosionen," Z. Physik 132, 54-71 (1952) (The Course of Wire Explosions)

E-87 ESCHENBACH, R. C., "Measuring Voltage in an Exploded Wire Discharge," Army Project 4A (July 1948)

B-3 KING, A. S., "Spectroscopic Phenomena of the High Current Arc," Astrophys. J. 62, 238-264 (1925)

E-120 KVARTSKHAVA, I. F., "Concerning Papers of E. S. Khaikin, S. V. Lebedev and B. N. Borodovskia, Published in the Zhur. Eksp. i Teoret. Fiz. (USSR) in 1954-1955" Zhur. Eksp. i Teoret. Fiz. 30 621 (1957), Soviet Phys. JETP 3, 787 (1956)

E-126 LANGWORTHY, J. B., O'ROURKE, R. C., SHULER, M. P., VITKOVITSKY, I. M., DOBBIE, C. V., VEITH, R. J., and HANSEN, D. F., "Electrically Exploded Wires — Experiment and Theory," Progress Report (1 Mar 58 - 30 April 60) N. R. Lab. Report 5489 (1961)

H-6 PARK, J. H., and CONES, H. N., "Puncture Tests on Porcelain Distribution Insulators Using Steep-Front Voltage Surges," Trans. Am. Inst. Elec. Engrs. 72, 1 (1953)

Production and measurement of steep front voltages.

H-7 PETERS, J. F., "The Klydonograph; an Instrument for Accurately Measuring and Recording Voltage Surges," Elec. World 83, 769-773 (1924)

(See H-5)

T-5 SLACK, C. M., and DICKSON, D. C., "One-millionth-second Radiography and Its Application," Proc. Inst. Radio Engrs. 35, 600-606 (1947)

H-8 TSAI, D. H., and PARK, J. H., "Calorimetric Calibration of the Electrical Energy Measurement in an Exploding Wire Experiment," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 97-107

A discussion is presented on the requirements and the methods for measuring the current and voltage during the transient discharge of a capacitor bank being employed in an exploding wire experiment. A method is described for accurately calibrating the measured current, voltage, and electrical energy by comparing the calorimetric heating of a resistance element of essentially constant resistance with the electrical energy dissipated in the element. Results show that the accuracy of the energy measurement is about 1-2 percent.

A-22 ZAREM, A. M., and MARSHALL, F. R., "A Method of Measuring Very High Speed Transient Currents," Rev. Sci. Instr. 20, 133-134 (1949)

E-6 ALLEN, W. A., HENDRICKS, C. H., MAYFIELD, E. B., and MILLER, E. M., "Electronic Shutter Photographs of Exploding Bridge Wires," Rev. Sci. Instr. 24, 1068-1069 (1953)

H-1 ALLIBONE, T. E., and MEEK, J. M., "The Development of Spark Discharge," Proc. Roy. Soc. (London) A166, 97-126 (1938) ibid A169, 246-268 (1938)

P-1 ANDERSON, J. A., "Spectral Energy-Distribution of the High-Current Vacuum Tube," Astrophys. J. 75, 394-406 (1932)

E-18 BARTELS, H., BORTFELDT, J., and BERG, K. H., "Über den Zündungsprozess bei Drahtexplosionen," Proc. of the Fifth International Conference on Ionization Phenomena in Gases, H. Maecker (ed), p. 1048-1051, North Holland Pub. Co., Amsterdam (1962) (On the Ignition Process in Wire Explosions)

L-1 BARTELS, H., and EISELT, B., "Über ein einfaches Verfahren zur kinematographischen Aufnahme schnell verlaufender Vorgänge," Optik 6, 56-58 (1950) (A Simple Method for Cinematographic Photography of Rapidly Occuring Processes)

E-27 BENNETT, F. D., "Flow Fields Produced by Exploding Wires," BRL Report 1075 (May 1959)

E-29 BENNETT, F. D., "Energy Partition in the Exploding Wire Phenomenon," BRL Report 1056 (Oct 1958)

E-30 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Phys. Fluids 1, 347-352 (1958)

E-31 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," BRL Report 1035 (1958)

E-34 BENNETT, F. D., and SHEAR, D. D., "Shock Waves from Exploding Wires at Low Ambient Densities," BRL Report 1152 (Oct 1961)

E-32 BENNETT, F. D., BURDEN, H. S., and SHEAR D. D., "Correlated Electrical and Optical Measurements of Exploding Wires," BRL Report 1133 (June 1961)

E-39 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," USNRL Prog. Report (1 Nov 1961 - 1 Feb 1962)

J-1 CHACE, W. G., and FISH, C. V., "Exploding Wire Blast Shutter," Appl. Optics 2, 441-443 (1963)

A capping shutter actuated by an electrically exploded copper ribbon is described. It is suitable for use with very-high-speed rotating mirror devices, since it has a closing time of <5μsec. Usable pictures may be taken even when the light intensity increases by 1000 between image repeats.

E-62 CLARK, G. L., HICKEY, J. J., KINGSLEY, R. J., and WUERKER, R. F., "Exploding Wire Driven Shock Waves," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 175-180

E-67 CONN, W. M., "Fenstermethode zur Beobachtung innerhalb von Metalldämpfen die bei kurzzeitigen Vorgängen auftreten Beispiel: Drahtexplosionen," Naturwissenschaften 45, 6-7 (1958) (Window Methods for Observation within the Metal Vapors Produced in Short Time Events. Example: Exploding Wires)

E-73 CONN, W. M., "The Use of 'Exploding Wires' as a Light Source of Very High Intensity and Short Duration;" J. Opt. Soc. Am. 41, 445-449 (1951)

H-5 COX, J. H., and LEGG, J. W., "The Klydonograph and Its Application to Surge Investigations," Trans. Am. Inst. Elec. Engrs. 44, 857-871 (1925)

N-3 EARLY, H. C., and MARTIN, E. A., "The Underwater Spark; a Photographic Light Source of High Intrinsic Brilliance," Trans. Am. Inst. Elec. Engrs. Pt. 1, 44, 788-790 (1955)

E-85 EISELT, B., "Über den Ablauf von Drahtexplosionen," Z. Physik 132, 54-71 (1952) (The Course of Wire Explosion)

J-2 FAYOLLE, P., and NASLIN, P., "Photographie Instantanée et Cinématographie Ultra-Rapide," Revue d'Optique Paris (1950) (Instantaneous Photography and High Speed Cinematography)

A most complete handbook of high speed photography.

N-5 FLOWERS, J. W., "The Channel of the Spark Discharge," Phys. Rev. 64, 225-235 (1943)

J-3 GIBSON, F. C., BOWSER, M. L., RAMALEY, C. W., and SCOTT, F. H., "Image Converter Camera for Studies of Explosive Phenomena," Rev. Sci. Instr. 25, 173-176 (1954)

An image converter camera is described.

J-4 GOSS, W. C., "Kerr-Cell Framing Camera," V Internat. Congress on High Speed Photog., Washington, p. 135-137 (1960)

A single Kerr Cell pulsed once is used with optical delays to provide framing type display at 15 X 10^{-8} sec/frame. A series of EBW's illustrates its use.

J-5 HEINE-GELDERN, R. V., "Photographie Ultra-Rapide au Moyen de Cellules de Kerr et de Fils Explosifs," Photographie and Cinématographie Ultra-Rapides, Actes du 2ème Congres International de Photographie et Cinématographie Ultra-Rapides, Paris (1954) p. 238-243 (High Speed Photography by Means of Kerr-cells and Exploding Wires)

Used E.W. for backlighting of explosive events. E.W. had maximum intensity of 5 X 10^8 candle power. Used 3 μF, 24 KV and Al wire. This same system fired the wire and opened the Kerr cell. Fired with three element spark gap, central element grounded. Required 5 μsec to attain full illumination.

J-6 HEINE-GELDERN, R. V., PUGH, E. M., and FONER, S., "Kerr Cell Photography of High Speed Phenomena-Detonation and Shock Phenomena," Phys. Rev. 79, 230 (1950)

An apparatus is described using an exploding wire to furnish light for Kerr cell photographs. Associated equipment and techniques are described.

J-7 HOLTZWORTH, R. E., and HINZ, D. J., "Exploding Wire Backlighting for the Study of Detonation, Shock and Shaped Charges," BRL Report 818 (May 1952)

The authors investigated E.W.P. as a light source and devised a practical system for its use.

E-126 LANGWORTHY, J. B., O'ROURKE, R. C., SHULER, M. P., VITKOVITSKY, I. M., DOBBIE, C. V., VEITH, R. J., and HANSEN, D. F., "Electrically Exploded Wires - Experiments and Theory," Progress Report 5489 NRL (1961)

J-8 LEVINE, M. A., and HEGARTY, J. C., "Shadowgraph of Self-Luminous Objects," Applied Optics 2, 78 (1963)

A Schlieren-like back-lighting system is described which emphasizes the back-light and decreases the brightness of the object. This makes detailed study easier. Illustrated with image converter photos of E.W.

J-9 LIDDIARD, T. P., and DROSD, R. D., "Exploding Wires for Light Sources in Fast Photography," U.S. Naval Ordnance Laboratory Memo 10840 (1950)

An investigation of the use of very small tungsten and nichrome wires for photography. Found tungsten preferable. Recommended inclosing wire in small glass capillary tubes.

J-10 LIEBING, L., and FRÜNGEL, F., "Multiple Kerr-Cell System with Square Shuttering Characteristics," V Internat. Congress on High Speed Photog., Washington, p. 138-140 (1960)

The system is completely coaxial - storage cable connecting cable, spark gap, switch, Kerr Cell, and terminator. A series of E.W. pictures illustrates its use.

E-134 LOCHTE-HOLTGREVEN, W., "Über die Elementarvorgänge bei der elektrischen Explosion dünner Metalldrähte," Tagung über Verbrennung, Stosswellen, Detonation, St. Louis (1951), Laboratorie de Research de St. Louis (France) 14/M/51 p. 325-337 (1951) (Concerning the Elementary Processes in the Electrical Explosion of Thin Metal Wires)

J-11 MARGETTS, D. R., and WOLFE, A. E., "Evaluation of an Image Converter as a High-Speed Camera Shutter," Jet. Propul. Lab. Caltec. Memo 20-131 (1956)

Resolution drops from 28/mm to 12/mm when stationary image is pulsed and displaced using magnetic focus and displacement. With lens aperture of f2 overall aperture is f32.

N-8 MARTIN, E. A., "The Underwater Spark: An Example of Gaseous Conduction at about 10,000 Atmospheres," Univ. of Michigan Res. Inst. 2048-12-F (July 1946)

F-4 MEINERS, D., BORTFELDT, J., WEBER, W., WITTIG, L., "Ein Verfchren Zur Messung des Absorptionskoeffizienten in inhomogenen und instationären Plasmasäulen mit höher optischer Schichtdicke," (A Method for Measuring the Absorption Coefficients in nonhomogeneous and nonstationary plasma columns with optical density, in Farschungsbericht K66-27, Bundesministerium für wissenschaftliche Forschung (Juli 1966) (Research Report K 66-27, Federal Ministry for Scientific Research (july 1966) (Germany)

E-143 MEL'NIKOV, M. A., and OBUKHOV, V. I., "Oscillographic Investigation of Electrical Wire Explosions," Izvestiia Vysshikh Uchebnykh Zavedenii. Energetike, 99-102 (1963)

E-148 MÜLLER, W., "Studies of Exploding Wire Phenomenon by Use of Kerr Cell Schlieren Photography," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 186-208

F-149 MÜLLER, W., "Der Ablauf einer electrischen Drahtexplosion mit Hilfe der Kerr-Zellen-Kamera untersucht," Z. Physik 149, 397-411 (1957) (Result of an Electric Wire Explosion Investigated by Means of the Kerr Cell Camera)

J-13 NADIG, F. H., BOHN, J. L., and KORNEFF, T., "High Speed Framing Camera for Photographing Exploding Wire Phenomena," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 345-364

Description of a multiple reflection, rotating mirror camera with a unique method of obtaining stationary images. Framing intervals of less than 1 μsec are possible.

E-151 NAGAOKA, H., and FUTAGAMI, T., "Cinematographic Sketch of Electrically Exploded Wires," Proc. Imp. Acad. (Japan) 4, 198-199 (1928)

E-153 NAGAOKA, H., and FUTAGAMI, T., "Electric Explosions," Sci. Papers Ins. Phys. and Chem. Res. (Tokyo) 8, 269-288 (1928)

E-154 NAGAOKA, H., and FUTAGAMI, T., "Instantaneous Photographs of Electrically Exploded Wires," Proc. Imp. Acad. (Japan) 2, 387-388 (1926)

H-7 PETERS, J. F., "The Klydonograph," Elec. World 83, 769-773 (1924)

A-16 PREUSS, L. E., "Image Formation of the Rapid Vaporization of Metal Filaments by the Sensitization and Autoradiographic Methods," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, (1959) p. 288-30[illegible]

J-14 PUGH, E. M., HEINE-GELDERN, R. V., FONER, S., and MUTSCHLER, E. C., "Kerr Cell Photography of High Speed Phenomena," J. Appl. Phys. 22, 487-493 (1951)

The authors used exploding wires to light a metal jet moving at about 1×10^5 cm per second, photographing with Kerr cells. Exploding Wire was used as a backlight.

J-15 SCHARDIN, H., and FÜNFER, E., "Grundlagen der Funkenkinematographie," Z. angew. Physik 4, 185-199, 224-238 (1952) (Physical Basis of Spark Cinematography)

Detailed review of spark cinematography including 53 references.

E-194 STRONG, C. L., "How to Make Extremely Energetic Sparks for High-S .ed Photography and Other Purposes," Sci. Am. 148-160 (Nov 1957)

J-16 SULTANOFF, M., "A 0.1 Microsecond Kerr-Cell Shutter," Photo. Eng. 5, 80-90 (1954)

A description of the Hycon model 26 commercial Kerr cell outfit. Some theory of the Kerr cell and a good bibliography.

J-17 THEOPHANIS, G. A., "A Kerr-Cell Camera with Synchronized Light Source for Millimicrosecond Reflected Light Photography," V Internat. Congress on High-Speed Photog., Washington, p. 129-134 (1960)

Description of camera, light source, and triggering equipment. A series of photos of exploding foils (brass and A1) illustrates use of the equipment.

E-204 TURNER, B. R., "A Study of Exploding Wires," Cal. Tech. Thesis (1960)

E-206 VAUDET, G., "Etude et emploi d'une Source Lumineuse de Grande Brillance," Ann. Phys. 9, 645-722 (1938) (The Study and Use of a Light Source of Great Brilliance)

U-9 WOFFINDEN, G. J., "Exploding Metal Films," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 193-210

J-18 ZAREM, A. M., MARSHALL, F. R., and HAUSER, S. M., "Millimicrosecond Kerr Cell Camera Shutter," Rev. Sci. Instr. 29, 1041-1044 (1958)

Description of their commercially available camera. Some details of construction and circuitry are given. The cell is operated by a special hydrogen thyratron and a modified transmission line pulse network made of RG58A/U. A set up for photographing E. W.'s is shown with three typical photographs.

J-19 ZERNOW, L., and HAUVER, G. E., "Cine-Microscopy of Sparks, Exploding Wires and Fracture at Framing Rates of 10^6 per Second," Phys. Rev. 98, 1551 (1955)

Microsecond framing camera photographs.

P-23 ZERNOW, L., and HAUVER, G. E., "High-Speed Cine-Microscopy and Space-Time Resolved Spectroscopy," in High Speed Photography, R. B. Collins (ed) Butterworth, London (1957) p. 305-314

J-20 ZERNOW, L., WOFFINDEN, G., and KREYENKAGEN, K. N., Soc. Photo. Sci. and Engrs. (Oct 1959) (Meeting Paper)

Similar to that presented at E. W. Conf. in Boston.

U-11 ZERNOW, L., and WOFFINDEN, G., "Cinemicrographic Study of Electrically Exploded Metal Foils," VI Internat. Congress on High-Speed Photog., The Hague p. 206-216 (1963)

Section J

J-21 ZERNOW, L., and WOFFINDEN, G. J., "The Cinemicroscopic Observation of Exploding Wires," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 170-185

W and Mo wires exploded with relatively low energy under 25 X microscopic cinegraph, at framing rates of 1.25×10^5 to 1.2×10^6 frames per sec.

E-221 ZERNOW, L., WOFFINDEN, G. J., and KREYENKAGEN, K. N., "High Speed Cinemicrography of Electrically Exploded Tungsten and Molybdenum Wires," Photo Science and Engineering 4, 31-36 (1960)

Similar to the work reported in E. W. Vol. I and Soc. Photo Scientists and Engineers meeting paper.

J-22 ZERNOW, L., WOFFINDEN, G. J., and WRIGHT, F., Jr., "High Speed Photographic Studies of Electrically Exploded Metal Films and Wires," Paper Presented at Fifth International Congress on High Speed Photography (1960)

Studied pure (99.95%) W and Thoriated W wires exploded quite slowly. Thoriated wire forms smaller more uniformly distributed bubbles. Suggests bubbles grow by nucleate boiling. Some study of films and investigation of a dwell phenomenon. Many high speed photomicrographs.

U-12 ZERNOW, L., WRIGHT, F., Jr., and WOFFINDEN, G. J., "High Speed Cinemicrographic Studies of Electrically Exploded Metal Films," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 245-262.

RESISTANCE – Section K

K-1 BARLOW, M., "Experiments on the Apparent Deviation from Ohm's Law for Metals at High Current Densities," Phil. Mag. 9, 1041 (1930)

Using Bridgman's AC-DC method with refinement, the author concludes no deviations up to 3×10^6 A/cm^2 for Pt and Au.

E-22 BENNETT, F. D., "High Temperature Cores in Exploding Wires," Phys. of Fluids 8, 1106-1108 (1965)

E-33 BENNETT, F. D., KAHL, G. D., WEDEMEYER, E. H., "Resistance Changes Caused by Vaporization Waves in Exploding Wires," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 65-88.

K-2 BONDARENKO, V. V., KVARTSKHAVA, I. F., PLIUTTO, A. A. and CHERNOV, A. A., "Resistance of Metals at High Current Densities," Zhur. Eksp. i Teoret. Fiz. 28, 191-198 (1955); Soviet Phys. JETP 1, 221-226 (1955)

The authors used E. W. P. techniques, but considered conditions only before the wire vaporized. Equipment and instrumentation described. Results given as curves of R vs. energy supplied.

K-3 BORODOVSKAYA, L. N., and LEBEDEV, S. V., "Dependence of the Electrical Conductivity and Electron Emission on the Energy of a Metal in the Process of Its Heating by a Current of High Density," Zhur. Eksp. i Teoret. Fiz. 28, 96-110 (1955); Soviet Phys. JETP 1, 71-83 (1956)

A study of the dependence of the resistance of Ni wire on the energy input to the wire in the region of 10^6 A/cm^2. Discontinuities were observed. Electron emission was similarly studied.

K-4 BOROVIK, E. S., "Electrical Conductivity of Metals at High Current Densities," Dokl. Akad. Nauk (USSR) 91, 771-774 (1953)

Author finds Pt, W, Cu obey Ohm's Law up to $j = 10^6$ A/cm^2, at this level Bi has 30-40% increase in R. Used constant current pulse method.

K-5 CHIOTTI, P., "Measurement of the Electrical Resistance of Metals and Alloys at High Temperatures," Rev. Sci. Instr. 25, 876-883 (1954)

Alternating current potentiometric methods for measuring resistance up to the melting point. The method of measuring, equipment, special recorders, and furnace used are described in detail.

E-76 DAVID, E., "Exploding Wires, Calculation of Heating," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 271-279

E-84 EDELSON, H. D., and KORNEFF, T., "Conducting Mechanisms for Exploding Wires in a Vacuum," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 267-284

E-95 GOOD, R. C., Jr., "Resistance Variation of Exploding Wires," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 23-25

K-6 IGNATYEVA, L. A., and KALASHNIKOV, S. G., "Electric Resistance of Metals to Pulses of High Current Density," Zhur. Eksp. i Teoret. Fiz. 22, 385-399 (1952)

K-7 LEBEDEV, S. V., and KHAIKIN, S. E., "Some Anomalies in the Behavior of Metals Heated by Current Pulses of Great Density," Zhur. Eksp. i Teoret. Fiz. 26, 629-639 (1956)

Measurements of resistance and of energy during E. W. P. shows anomalies when current density approaches $10^7 A/cm^2$. Energy to raise to the melting point is in excess of the theoretical if time is less than 5×10^{-4} sec.

E-133 LEVINE, P. H., TOLLESTRUP, A. V., and WEBB, F. H., Jr., "Electrical Conduction in Rapidly Exploded Wires," Proc. of the Fifth Internat. Conf. on Ionization Phenomena in Gases, Vol. II, H. Maecker (ed), p. 2034-2054, North-Holland Pub. Co., Amsterdam (1962)

E-139 MANINGER, R. C., "Preburst Resistance and Temperature of Exploding Wires," U. of Cal. (Livermore) UCRL-7613 (1964)

K-8 MANKA, C. K., and ZINKE, O. H., "Observed Dwells in Current through a Pulsed Argon Plasma," Phys. of Fluids 8, 1186 (1965)

The authors observe periods of zero current in plasma discharges which they compare with dwells in E. W.

K-9 MARGENAU, H., "Die Abweichungen vom Ohmeschen Gesetz bei hohen Stromdichten im lichte der Sommerfeldschen, Elektronontheorie," Z. Phys. 56, 259-261 (1929) (The Deviation from Ohm's Law at High Current Density in the Light of Sommerfeld's Electron Theory)

A consideration of conductivity from Sommerfeld's theory using Fermi statistics. Results differ by an order of magnitude from classical theory.

K-10 NORINDER, R. H., and KARSTEN, O., "Experimental Investigations of Resistance and Power Within Artificial Lightning Current Paths," Ark. Mat. Astron. Fysik 36A, 1-48 (1949)

Thorough discussion of experimental and theoretical investigation of resistance and power, in discharges of an impulse generator at voltages as high as 2000 KV. (In English)

K-11 POWELL, R. W., "Thermal Conductivities of Molten Metals and Alloys," J. Iron and Steel Inst. (London) 162, 315-324 (1949)

A collection of thermal and electrical data, mostly thermal; and discussion of relations between measurable quantities.

E-170 PROTOPOPOV, N. A., and KUL'GAVCHUK, V. M., "Mechanism for Interruption of Current Flow and Production of Shock Waves in a Metal Heated by High-Density Current Pulses," Zhur. Tech. Fiz. 31, 557-564 (1961) Trans. in Soviet Phys. - Tech. Phys. 6, 399-404 (1961)

K-12 SHABANSKII, V. P., "On Deviation from Ohm's Law in Metals," Zhur. Eksp. i Teoret. Fiz. 27, 147-155 (1954)

The author presents theoretical evidence that deviations should exist when applied field is strong enough, due to delay in transfer of energy from electrons to the lattice.

E-200 TUCKER, T. J., "Behavior of Exploding Gold Wires," J. Appl. Phys. 32, 1894-1900 (1961)

K-13 VERESHCHAGIN, L. F., SEMERCHAN, A. A., KUZIN, N. N., and POPOVA, S. V., "The Variation of the Electrical Resistance of Some Metals Up to Pressures of 200,000 Kg/cm^2," Doklady Akad. Nauk SSSR 136, 320-321 (1961) Trans in Soviet Phys. - Doklady 6, 41-42 (1961)

Resistance of Sb, As, Ca. Discontinuity in ρ for Sb at 1.3×10^5 Kg/cm^2 similar to that in Bi at 1.4×10^5 Kg/cm^2. ρ increases 50%. ρ decreases again after the discontinuity. As has no discontinuity up to 200,000 Kg/cm^2. Ca resistance increases uniformly with increasing pressure. Others decrease except at discontinuity.

E-208 WEBB, F., "Study of Electrically Exploded Wire Materials," ESO Report 210-QL -7 (May 1960), Electro-Optical Systems, Inc. Quarterly Progress Report.

ROTATING MIRRORS – Section L

H-1 ALLIBONE, T. E., and MEEK, J. M., "The Development of the Spark Discharge," Proc. Roy. Soc. (London) A166, 97-126 (1938), ibid, A169, 246-268 (1938)

L-1 BARTELS, H., and EISELT, B., "Über ein einfaches Verfahren zur kinematographischen Aufnahme schnell verlaufender Vorgänge," Optik 6, 56-58 (1950) (A Simple Method for Cinematographic Photography of Rapidly Occurring Processes)

A rotating mirror, multiple image camera using a series of stationary mirrors to form several images. Illustrated with a series from a wire explosion.

M-6 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Bull. Am. Phys. Soc. 3, 292 (1958)

E-30 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Phys. Fluids 1, 347-352 (1958)

E-31 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," BRL Report 1038 (1958)

Section L

Eb-3 BLACKBURN, J. H., and REITHEL, R. J., "Exploding Wire Detonators: Sweeping Image Photographs of Exploding Bridgewire Initiation of PETN," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964), p. 153-173

E-93 FUTAGAMI, T., "On the Electric Explosion Spectrum of Metals," Sci. Papers Inst. Phys. Chem. Research (Tokyo) 31, 1-29 (1937)

L-2 GORDON, G., and CADY, W. M., "Rotating Mirror Optical System," J. Opt. Soc. Am. 40, 852-853 (1950)

A rotating mirror spectrograph suitable for study of sparks and E. W. P. is described; timing by photoelectric tube. The energies used were low.

J-13 NADIG, F. H., BOHN, J. L., and KORNEFF, T., "High Speed Framing Camera for Photographing Exploding Wire Phenomenon," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959) p. 345-364

J-19 ZERNOW, L., and HAUVER, G., "Cine-Microscopy of Sparks, Exploding Wires and Fracture at Framing Rates of 10^6 per Second," Phys. Rev. 98, 1551 (1955)

SHOCK WAVES – Section M

M-1 BAIRD, K. M., "Shock Waves in Glass," Nature 160, 24-25 (1947)

The author produced shock waves by exploding copper wire sealed in pyrex rod.

E-19 BARTELS, H., and BORTFELDT, J., "Some Experimental Results of Exploding Wire Research and Their Applications in Plasma Physics," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 9-21

E-25 BENNETT, F. D., "Shock-Producing Mechanisms for Exploding Wires," Phys. of Fluids 5, 891-898 (1962)

E-24 BENNETT, F. D., "Exploding Wires," Scientific American 206, 103 (May 1962)

E-26 BENNETT, F. D., "Shock Producing Mechanisms for Exploding Wires," BRL Report 1161 (Feb. 1962)

M-2 BENNETT, F. D., "Cylindrical Shock Waves from Exploded Wires of Hydrogen-Charged Palladium," BRL Report 1063 (January 1959)

Since stronger shocks are produced when the driving gas has higher sound speed than driven, it was hoped to produce stronger E. W. shocks with Pd-H loaded. The H_2 came out during preliminary heating hence the wires had to be H_2 loaded then Cu plated. Then strong shocks are produced. The process, however, now has become very complex. More study is indicated.

M-3 BENNETT, F. D., "Cylindrical Shock Waves from Exploded Wires of Hydrogen-Charged Palladium," Phys. Fluids 2, 470-471 (1959)

(See M-2)

M-4 BENNETT, F. D., "Flow Fields Produced by Exploding Wires," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 211-226

A discussion of shocks produced by exploding fine cylindrical wires. The similarity flows of Lin, Guderleg and Weizsäker are discussed and compared with experimental results.

E-27 BENNETT, F. D., "Flow Fields Produced by Exploding Wires," BRL Report 1075 (May 1959)

E-28 BENNETT, F. D., "Energy Partition in the Exploding Wire Phenomenon," BRL Report 1056 (Oct 1958)

E-29 BENNETT, F. D., "Energy Partition in the Exploding Wire Phenomena," Phys. Fluids 1, 515-522 (1958)

E-33 BENNETT, F. D., KAHL, G. D., WEDEMEYER, E. H., "Resistance Changes Caused by Vaporization Waves in Exploding Wires," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 65-88.

M-5 BENNETT, F. D., and SHEAR, D. D., "Shock Waves from Exploding Wires at Low Ambient Densities," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 181-194

The recently discovered technique of streak interferometry has been applied to study of EW at reduced pressures. At 1/15 atm an intensely luminous peripheral arc forms in an annulous several mm from the wire. Near the tip, measured fringes are negative, radiating electrons. No shock wave is seen. In 1 μsec the fringe shifts near the periphery to positive and shocks appear. Electron densities as high as 10^{18} cm^{-3} in annular region. A sequence of interferograms at pressures of 1/16 to 1 atm is presented, and implications for the mechanism of shock production are discussed.

E-35 BENNETT, F. D. and SHEAR, D. D., "Shock Waves from Exploding Wires at Low Ambient Densities," BRL Report 1152 (Oct 1961)

A-3 BENNETT, F. D., and SHEAR, D. D., "Visualization of Cylindrical Shock Waves," Phys. Fluids 2, 338-339 (1959)

A-2 BENNETT, F. D., and SHEAR, D. D., "Visualization of Cylindrical Shock Waves," BRL Memo Report 1199 (March 1959)

A-4 BENNETT, F. D., SHEAR, D. D., and BURDEN, H. S., "Streak Interferometry," J. Opt. Soc. Am. 50, 212-216 (1960)

M-6 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Bull. Am. Phys. Soc. 3, 292 (1958)

Abstract of paper. Rotating mirror and streak camera pictures of exploding wires producing shock waves. Using Pd-H, might get enhanced shocks.

A-5 BENNETT, F. D., SHEAR, D. D., and BURDEN, H. S., "Streak Interferometry," BRL Report 1080 (Sep 1959)

Eb-3 BLACKBURN, J. H., and REITHEL, R. J., "Exploding Wire Detonators: Sweeping-Image Photographs of Exploding Bridgewire Initiation of PETN," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 153-173

E-62 CLARK, G. L., HICKEY, J. J., KINGSLEY, R. J., and WUERKER, R., F., "Exploding-Wire-Driven Shock Waves," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 175-180

E-69 CONN, W. M., "Studies of the Mechanism of Electrically Exploded Wires," Naturwissenchaften 42, 65-66 (1955)

E-70 CONN, W. M., "Studien zum Mechanismus von elektrischen Draht explosionen (Metall niederschläge Und Stosswellen)," Z. angew Physik 7, 539-554 (1955) (Studies on the Mechanism of Electrical Wire Explosions)

E-71 CONN, W. M., "Metallic Deposits and Shock Waves Due to Electrically Exploded Wires," Phys. Rev. 98, 1551 (1955)

M-7 DENNEN, R. S., and WILSON, L. N., "Electrical Generation of Imploding Shock Waves," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 145-157

Imploding shock waves have been generated by electrically exploding thin metallic films from the inner surface of glass cylinders. Preliminary measurements of the resulting shock motion show close

agreement with the predictions of constant-energy similarity analyses. In contrast to the exploding shock wave, the imploding wave appears to be inherently unstable. While irregularities in the surface of the wave are evident, particularly near the Implosion center, Schlieren photographs showed a fairly symmetrical wave structure.

Eb-4 DiPERSIS, R., "Exploding Wire and Spark Gap Central Initiator for High Explosives," BRL Memo Report No. 851 (Oct 1954) AD No. 59600

M-8 FYFE, I. M., and EMSINGER, R. R., "Explosive Wire Induced Cylindrical Waves in Solids," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 257-265.

Explosion of a wire along the axis of a cylindrical specimen is used in the study of stress waves in solids. Stress waves produced in this fashion give deformations that are symmetric and completely uniform along a large portion of the specimen. This type of deformation allows a close experimental approximation to tractable propagation theories in solids. High-speed photographs together with measurements obtained using imbedded pins, etc., is used to confirm the existence of uniform deformations. Application of this method to the problem of "hydromagnetic" deformation of solids under impulsive loading is used as an illustration of the techniques and measurements.

M-9 HALPIN, W. J., and HENDRICKS, R. E., "The Use of Pressure Bars and Plates for the Investigation of Shock Waves from Electrically Exploded Wires," Sandia Tech. Memo SCTM 39-60 (51) (1960)

Hopkinson pressure bar (Al rod with barium titanate plate cemented on) used to investigate shocks produced by E. W.'s (4" of No. 28 Cu). The effects of varying voltage, wire size, wire material on shock waves produced by the wire were reported. Concluded that pressure bars and plates are useful tools for study of E. W. shock waves.

E-101 HERZOG, A., "Influence of Short Time, High Velocity Impact on Materials Structures," Tech. Memo WCRT 56-93, Wright Air Development Center, Materials Laboratory (Aug 1956)

J-7 HOLTZWORTH, R. E., and HINZ, D. J., "Exploding Wire Backlighting for the Study of Detonation, Shock and Shaped Charges," BRL Report 818 (May 1952)

M-10 JONES, D. L., "Precursor Electrons Ahead of Cylindrical Shock Waves," Phys. Fluids 5, 1121-1122 (1962)

Ionization was found ahead of the shock waves from exploding wires. Microwave absorption at 25 and 35 Gc (λ = 1.2 and 0.84 cm) was used. Doppler measurements. The ionization spreads out far ahead of the shock, suggesting that it is produced by the uv in the shock. Time between explosion and observation of electrons depends

on gas and pressure. It can be as long as 160 μsec. Wire was 6.8 mil Cu., 4 cm long, 180 J/cm input. Pressure 50 cm.

M-11 JONES, D. L., and EARNSHAW, K. B., "A Wire Exploder for Generating Cylindrical Shock Waves in a Controlled Atmosphere," NBS Technical Note No. 148 (Feb 1962)

Description of a device which permits the study of strong cylindrical shock waves in controlled atmospheres using optical and microwave techniques. Voltages up to 20 kv. Current to 150 ka. Low inductance in spite of remote current return. Pressures down to 50μ.

M-12 JONES, D. L., and GALLET, R. M., "Microwave Doppler Measurements of the Ionization Front in Cylindrical Shock Waves from Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 127-144

Microwave Doppler measurements on E.W.'s show ionization front well defined and Taylor-Lin similarity theory well verified for 6 to 7 cm. This technique is more sensitive and precise than optical methods. It is remarkable that good reflections are obtained when shock Mach number falls below 3 in air. There is a weak precursor ionization with electron densities of 10^{11} cm^{-3} several centimeters ahead of the front.

X-25 KELLER, D. V., and PENNING, J. R., Jr., "Exploding Foils — The Production of Plane Shock Waves and the Acceleration of Thin Plates," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 263-277

U-5 KELLER, D. V., and TRULIO, J. G., "Mechanism of Spall in Lucite," J. Appl. Phys. 34, 172-175 (1963)

E-113 KESSLER, M., "Conception and Installation of an Electrical High Energy Discharge Unit," Watertown Arsenal Lab. WAL TN 126. 1/1 (Oct 1962)

M-13 KOTOV, Yu., A., and MEL'NIKOV, M. A., "Recording Shock Waves and Exploding Wire Characteristics," Elektronnaya obrabotko materialov No. 3, 28-32 (1966)

Description of a system for producing shock-waves with controllable parameters. The shocks are produced from E.W.'s whose current and voltage are recorded. Careful synchronization between the various elements of the system is provided.

E-117 KUL'GOVCHUK, V. M., "Development of Luminous Zones in Electrical Detonation of Thick Wires," Zh. Priklad. Mekh. i Tekhnich. Fiz. 4, 165-168 (1965)

E-124 KVARTSKHAVA, I. F., PLIUTTO, A. A., CHARNOV, A. A., and BONDARENKO, V. V., "Electrical Explosion of Metal Wires," Zhur. Eksp. i Teoret. Fiz. 30, 42-53 (1956) Soviet Phys. JETP 3, 40-51 (1956)

Eb-7 LEOPOLD, H. S., "Effect of Energy Termination on the Initiation of PETN by Exploding Wires," NOLTR 65-56 (1965)

M-14 LIN, S., "Cylindrical Shock Waves Produced by Instantaneous Energy Release," J. Appl. Phys. 25, 54-57 (1954)

Theoretical (mathematical) consideration of shock waves from cylinders in the atmosphere. Thin wire is considered as a typical source of the shock wave.

R-6 LOCHTE-HOLTGREVEN, W., "Production and Measurement of High Temperatures," Reports Progress Phys. 21, 312-383 (1958)

E-134 LOCHTE-HOLTGREVEN, W., "Über die Elementarvorgänge bei der elektrischen Explosion dünner Metalldrähte," Tagung über Verbrennung, Stosswellen, Detonation, St. Louis (1951) Laboratoire de Research de St. Louis (France) 14/M/51 p. 325-327 (1951) (Concerning the Elementary Processes in the Electrical Explosion of Thin Metal Wires.)

M-15 MICHEL-LEVY, A., and MUROAUR, H., "Sur la luminosité des ondes de choc," Comptes-Rend. 198, 1760-1762 (1934) (Concerning the Luminosity of Shock Waves)

The authors observe the same type of continuous spectra that Anderson reported from confined E.W.'s and hypothesize that his were actually spectra of the shocks due to the E.W.

E-150 McGRATH, J. R., "Scaling Underwater Exploding Wires," J. Appl. Phys. 37, 4439-4443 (1966)

E-148 MULLER, W., "Studies of Exploding Wire Phenomenon by Use of Kerr Cell Schlieren Photography," Exploding Wires, Vol. 1, Chace and Moore (eds), Plenum Press, New York (1959) p. 186-208

E-149 MULLER, W., "Der Ablauf einer electrischen Drahtexplosion mit Hilfe der Kerr-Zellen-Kamera untersucht," Z. Physik 149, 397-411 (1957) (Result of an Electric Wire Explosion Investigated by Means of the Kerr Cell Camera)

M-150 McGRATH, J. R., "Scaling Underwater Exploding Wires," J. Appl. Phys. 37, 4439-4443 (1966)

A comparison of underwater explosion of wires and chemical (TNT) explosives. Peak pressure and decay time constant of the shock wave are compared. It is found that peak pressure reduces to the same kind of similitude functions as those used for TNT if circuit losses are included. Reduced time constant also reduces to same kind of similitude function. Magnitude and behavior of reduced time constant are comparable to TNT.

E-157 NASH, C. P., and McMillan, W. G., "On the Mechanism of Exploding Wires," Phys. Fluids 4, 911-917 (1961)

E-166 O'ROURKE, R. C., SCHERRER, V., and DOBBIE, C. B., "Production of Strong Cylindrical Shock Waves by Exploding Wires," Bull. Am. Phys. Soc. 2, 47 (1957)

M-17 OSHIMA, K., "Blast Waves Produced by Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 159-174

This paper is concerned mainly with the cylindrical blast wave produced by a wire explosion. In order to obtain a strong blast wave the wire was exploded in a shock chamber evacuated to low pressure. Density distributions of air were observed with a Mach-Zehnder interferometer. The processes of formation and propagation as well as the internal structures of the blast wave were analyzed.

Taylor-Lin-Sakurai's first approximation and Sakurai's second approximation for strong cylindrical blast waves were made in the analysis of data. For the analysis of moderately strong blast waves.

A newly presented theory, called quasi-similarity theory, was applied. This theory is based on the assumption that the distributions of the flow velocity, density, and pressure are locally similar. Agreement of experimental results with the corresponding theoretical predictions was satisfactory.

M-18 OSHIMA, K., "Blast Waves Produced by Exploding Wires," Aeronautical Res. Inst., Univ. of Tokyo 26, Report 358 (1960)

A comparison of experiments with theory. Compared with Sakuri's first and second approximations for strong shocks. A new theory is proposed called "quasi-similarity theory" which predicts intermediate stages of decay. A theory of formation and propagation is described which includes several cases.

E-170 PROTOPOPOV, N. A., and KUL'GAVCHUK, V. M., "Mechanism for Interruption of Current Flow and Production of Shock Waves in a Metal Heated by High-Density Current Pulses," Zhur. Tech. Fiz. 31, 557-564 (1961), Trans. in Soviet Phys. - Tech. Phys. 6, 399-404 (1961)

M-19 RODERS, H., "Ein Stosswellenrohr mit aufheizung der Hochdruchfullung durch eine starke Kondensatorentladung," (A Shock Tube with Heating of the High Pressure Chamber by Means of Powerful Capacitor Discharge) in Forschungsbericht K66-27, Bundesministerium fur wissenschaftliche Forschung (Juli 1966) (Research Report K 66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

Enhancement of shock wave velocity by heating the gas within the driver section of a conventional shock tube by means of a discharge initiated by an E. W.

E-175 ROSE, G. S., "Wire Explosions in Air and In Vacuo," J. Appl. Phys. 33, 1604-1606 (1962)

E-176 ROUSE, C. A., "Theoretical Calculations of Exploding Wire Phenomenon," Univ. of California Lawrence Radiation Lab., UCRL-5684-T (1959)

M-20 ROUSE, C. A., "Theoretical Analysis of the Hydrodynamic Flow in Exploding Wire Phenomena," Univ. of California (Livermore)-UCRL 5519-T (1959)

A theoretical calculation using IBM 704 Lagrangian code of flows from instantaneous energy depositing. Results are given for different equations of state for the wire and for air. Resultant shock wave calculations are compared with the observations of Bennett.

M-21 ROUSE, C. A., "Theoretical Analysis of the Hydrodynamic Flow in Exploding Wire Phenomena," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 227-263

Theoretical calculations by 704 computer, assuming instantaneous deposition of energy in wire. Calculated with (1) different equation of state for copper (2) different equation of state for air (i.e., constant γ law and variable γ law). Shock waves require different energies.

M-22 SAKURAI, A., "On the Propagation of Cylindrical Shock Waves," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 264-270

Taylor-type solution for the strong cylindrical shock from a line source is improved for later stages by expanding solution of basic gas dynamic equation in a series of $(c/u)^2$. This allows a better estimate of energy to produce the shock.

E-179 SAKURAI, A., and TAKAO, T., "Effect of Applied Axial Magnetic Field on the Exploding Wire Phenomenon," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 247-256

M-23 SCHALL, R., and THOMER, G., "Röntgenblitzaufnahmen von Stosswellen in festen, flussigen, und gasformigen Medien," Z. angew. Physik 3, 41-44 (1951) (X-ray Flash Photographs of Shock Waves in Solid Liquid and Gaseous Media)

The authors used exploding ribbons as a source of shock waves. These waves were studied by flash x-rays.

M-24 TODD, J., Jr., "A Photographic Study of Sources of Spherical Shock Waves," SCTM-242-54 (51) (Nov 1954)

E.W.'s produce nearly spherical shocks at radius of 6 to 8 inches.

Section M

E-204 TURNER, B. R., "A Study of Exploding Wires," Cal. Tech. Thesis (1960)

E-205 VANYUKOV, M. P., and ISAENKO, V. I., "Investigation of Light Produced by Exploding Wires," Zh. Techn. Fiz. 32, 197-201 (1962) Trans. in Soviet Physics-Tech. Phys. 7, 138-142 (1962)

R-12 VANYUKOV, M. P., and MAK, A. A., "High-Intensity Pulsed Light Sources," Uspekhi Fiz. Nauk. 66, 301-329 (1958), Trans. in Soviet Phys. - Uspekhi 66, 137-155 (1958)

E-212 WEBB, F. H. Jr., HILTON, H. H., LEVINE, P. H., and TOLLESTRUP, A. V., "Exploring the Nature of Bridgewire Explosions," Space/Aeronautics, 75-80. (Aug 1962)

SPARKS – Section N

N-1 ABRAMSON, L. S., and MARSHAK, I. S., "A High-Power Electric Spark in Air at Atmospheric Pressure," Zh. Tech. Fiz. 12, 632-639 (1942)

Primarily a study of high-current sparks, but the authors use wire explosion as a means of "confining" the spark channel and observe "dwell and restrike" and discuss it, suggesting more work.

H-1 ALLIBONE, T. E., and MEEK, J. M., "The Development of the Spark Discharge," Proc. Roy. Soc. (London) A166, 97-126 (1938), ibid A169, 246-268 (1938)

E-7 ALLISON, S. K., and HARKINS, W. D., "The Absence of Helium from Gases Left after the Passage of Electrical Discharges," J. Am. Chem. Soc. 46, 814-824 (1926)

C-1 BELLASCHI, P. L., "Lightning Currents in Field and Laboratory," Elec. Eng. 54, 837-843 (1935).

E-30 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," Phys. Fluids 1, 347-352 (1958)

E-31 BENNETT, F. D., "Cylindrical Shock Waves from Exploding Wires," BRL Report 1038 (1958)

N-2 BLOXSOM, D. E., "Production of High Temperature, Moderate Pressure Gases by Means of Electric Spark Discharges," Arnold Eng. Dev. Cent. AEDC-TN-56-17 (1956)

Discharged condenser into glass chamber and noted rise in temperature. Discharge initiated by E. W. P. Varying the E. W. P. initiator did not effect results, hence following arc was the important feature.

Eb-4 DiPERSIS, R., "Exploding Wire and Spark Gap Central Initiator for High Explosives," BRL Memo Report No. 851 (Oct 1954) AD No. 59600

N-3 EARLY, H. C., and MARTIN, E. A., "The Underwater Spark: a Photographic Light Source of High Intrinsic Brilliance," Trans. Am. Inst. Elec. Engrs. Pt 1, 44, 788-790 (1955)

By exploding wires under water, pressure of explosion is increased. Temperature estimated at 4.4×10^4 degrees C. Instantaneous spectra are obtained through a "shatter shutter."

N-4 FINKELNBURG, W., "Continuous Electron Radiation in Gas Discharges," Phys. Rev. 45, 341-342 (1934)

A discussion of continuous spectra produced by "Condensed discharges" of which E. W. P. is one.

N-5 FLOWERS, J. W., "The Channel of the Spark Discharge," Phys. Rev. 64, 225-235 (1943)

Although the discussion is entirely about sparks, the techniques are of interest to workers in E. W. P. Moving film camera, current, voltage and light measure equipment are described. There is a discussion of the theory of sparks including the relation of sparks to the sound produced.

E-100 HEGE, J. S., "Determination of the Total Thermal Radiant Energy Emitted by an Underwater Exploding Wire," USN Radiological Def. Lab. USNRDL-TR-612 (Jan 1963)

E-104 v. HUBL, A., and v. OBERMAYER, A., "Über einige elektrische Entladungserscheinungen und three photographische Fixierung," Sitzungber. d. K. Akad. Wissenschzu, Wein 98, Abth IIa, 419-430 (1889) (On the Appearance of Several Electrical Discharges, and their photographic Recording)

N-6 LAWRENCE, E. O., and DUNNINGTON, F. G., "On the Early Stages of Electric Sparks," Phys. Rev. 35, 396-407 (1930)

Although the authors refer to E. W. P. only incidentally, their Kerr cell equipment is of interest.

N-7 MARTIN, E. A , "Experimental Investigation of a High-Energy Density, High-Pressure Arc Plasma," J. Appl Phys. 31, 255-267 (1960)

A spark is initiated by exploding a 1 mil W wire under water. The resulting spark is studied by energy balance methods. The wire is assumed to have no effect on the spark. Temperature is estimated (ca, 30,000°K) by considering the gas to act as a blackbody at the pressures involved. Kerr cell photos were used to measure channel diameter. A pressure of 8300 atmos. was found.

N-8 MARTIN, E. A., "The Underwater Spark: An Example of Gaseous Conduction at about 10,000 Atmospheres," Univ. of Michigan 2048-12-F (July 1956)

Discusses arc underwater using W wire to initiate the arc. Investigated by measuring current, light output, and by taking Kerr cell photographs. Calculated pressure and temperature.

J-15 SCHARDIN, H., and FÜNFER, E., "Grundlagen der Funkenkinemetographie," Z. angew. Physik 4, 185-199 (1952) and Z. angew. Physik 4, 224-238 (1952) (Physical Basis of Spark Cinematography)

N-9 SMITH, H. L., and EARLY, H. C., "Experimental Studies of Underwater Sparks," Tech. Report Office of Ordnance Research, Ord. Corps, U.S. Army, Project 2048 (July 1953)

The authors studied the light output of sparks initiated by E.W.P. underwater.

X-38 WAGNER, H. J., and BOULGER, F. W., "High Velocity Metalworking Processes Based on the Sudden Release of Electrical Energy," Battelle Memorial Institute, Defense Metals Information Center, DMIC Memo 70 (Oct 1960)

J-19 ZERNOW, L., and HAUVER, G., "Cine-Microscopy of Sparks, Exploding Wires, and Fractures at Framing Rates of 10^6 per second," Phys. Rev. 98, 1551 (1955)

SPECTROSCOPY – Section P

E-9 ANDERSON, J. A., "Electrically Exploded Wires," International Critical Tables, Vol. 5, 434 (1929) McGraw-Hill, New York

P-1 ANDERSON, J. A., "Spectral Energy-Distribution of the High-Current Vacuum Tube," Astrophys. J. 75, 394-406 (1932)

The author studied the spectrum and absolute brightness of light emitted from the discharge of high current through a small diameter tube, partially evacuated at a current density of 10^4 amperes per cm^2, a continuous spectrum was produced independent of electrode and gas composition. Absolute intensity corresponds to a blackbody above 10^4 degrees K.

E-10 ANDERSON, J. A., "Spectral Distribution and Opacity of Wire Explosion Vapors," Proc. Nat. Acad. Sci. U.S. 8, 231-232 (1922)

E-11 ANDERSON, J. A., "Spectra of Explosions," Proc. Nat. Acad. Sci. U.S. 6, 42-43 (1920)

E-12 ANDERSON, J. A., "The Spectrum of Electrically Exploded Wires," Astrophys. J. 51, 37-48 (1920)

E-18 BARTELS, H., BORTFELDT, J., and BERG, K. H., "Über den Zindüngsprozess bei Drahtexplosionen," V. Internat. Conf. on Ionization Phenom. in Gases, Munich, (1961) p. 1047-1051 (On the Ignition Process in Wire Explosion)

R-1 BEHRENS, W., "Temperatur Bestimmung bei Elektrischen Draht Explosionen," Dis. Hannover 1935 Abs. in Physik Ber 16, 1958 (1935) (Temperature Determination in Electric Wire Explosions)

E-37 BEUCHELT, R., and BÖHM, E., "Über eine Temperatur und Druckmessung im Plasma von Drahtexplosionen," Naturwissenschaften 44, 507 (1957) (Temperature and Pressure Measurement in the Plasma from Exploding Wires)

E-38 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S.N. Res. Lab. Prog. Rept. 1 Feb - 1 May 1962

T-1 BEY, P. P., FAUST, W. R., FULPER, R., HARRINGTON, F. D., LEAVITT, G. E., SHIPMAN, J. D., and VITKOVITSKY, I. M., "Exploding Wire Studies," NRL Prog. Report (1 Aug to 1 Nov 1961)

P-2 BODSON, E., and DEHALU, F., "Nouvelles récherches sur les bandes de l'oxyde d'aluminum," Bull. Acad. Belg. 23, 408 (1937) (New Research on the Bands of Aluminum Oxide)

Principally theoretical spectroscopy. The oxide was produced by 'exploding' wire with a battery source.

P-3 CASE, R. S., Jr., "Time Resolved Spectroscopy of Exploding Wires," Thesis, AFIT GSP/PH/ 66-2 (1966)

Equipment is described by which satisfactory time resolved spectra of exploding wires may be made. Line broadening and submicrosecond studies, however, were not successful. Computer programs written in Fortran IV are given for resistance, voltage, power, and energy and also for wavelength, time and temperature.

E-45 CASSIDY, E. C., and ABRAMOWITZ, S., "Watching a Wire Explode," New Scientist 31, 136 (1966)

F-1 CASSIDY, E. C., and ABRAMOWITZ, S., Studies of Some Exploding Wire Light Sources," J. Soc. Mot. Picture and T. V. Engrs. 75, 734-737 (1966)

P-4 COHEUR, F. P., "Contributions a l'étude du spectre de bands de la molecule TiO," Bull. Soc. Roy. Sci. Liege 12, 98-103 (1943) (Contributions to the Study of the Band Spectrum of the TiO Molecule)

A wire (first a Ti wire, later a Cu wire loaded with TiO_2 powder) was exploded by connecting it across a 110 volt dc battery, resulting in the passage of 100 amps. The resulting band spectra were studied.

P-5 COHEUR, F. P., and ROSEN, B., "Le spectre des bandes de l'oxyde d'aluminum," Bull. Soc. Roy. Sci. Liege 10, 405-413 (1941) (The Band Spectrum of Aluminum Oxide)

The problem was to study the formation of aluminum oxide (A1O) when A1 wire was exploded using a 110 volt battery.

E-69 CONN, W. M., "Studies of the Mechanism of Electrically Exploded Wires," Naturwissenschaften 42, 65-68 (1955)

E-70 CONN, W. M., "Studien zum Mechanismus von electrischen Drahtexplosionen (Metallnieder schläge und Stosswellen)," Z. angew. Physik 7, 539-554 (1955) (Studies on the Mechanism of Electrical Wire Explosions)

P-6 DELSEMME, A., and ROSEN, B., "Spectre de FeO," Bull. Soc. Roy. Sc. Liege 14, 70-80 (1945) (The Spectrum of FeO)

The spectrum was produced by "exploding" a wire with a battery of 50-100 volts. The switching was a rotating disc which also had a slot used as a shutter.

B-2 DIEKE, G. H., "Study of Variations in Light Sources as They Effect Spectroscopy," ASTM Tech. Pub. No. 76, 37 (1946)

E-82 ECKSTEIN, L., and FREEMAN, I. M., "Das Spektrum Explodierender Lithiumdrähte," Z. Physik 64, 547-555 (1960) (The Spectrum of Exploded Lithium Wires)

E-90 FAUST, W. R., FULPER, R. Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., VITKOVITSKY, I. M., HARRINGTON, F. D., and McMAHON, J. M., "Exploding Wire Studies," NRL Progress Report 1 May to 1 August 1962

N-4 FINKELNBURG, W., "Continuous Electron Radiation in Gas Discharges," Phys. Rev. 45, 341-342 (1934)

E-93 FUTAGAMI, T., "On the Electric Explosion Spectrum of Metals," Sci. Papers Inst. Phys. Chem. Research (Tokyo) 31, 1-29 (1937)

E-99 HAUVER, G. E., "A Spectrograph with Space-Time Resolution and Its Application to the Study of Exploding Tungsten Wires," BRL Report 913 (July 1955)

E-102 HORI, T., "On the Absorption Spectra Produced by the Explosion of Various Elements (Hg, Cu, Fe, etc.)," Sci. Papers Inst. Phys. Chem. Research (Tokyo) 4, 59-78 (1926)

B-3 KING, A. S., "Spectroscopic Phenomena of the High-Current Arc," Astrophys. J. 62, 238-264 (1925)

P-7 KNAUSS, H. P., and BRYAN; A. L. "Spectral Characteristics of Electrically Exploded Mercury," Phys. Rev. 47, 842-844 (1935)

> The spectrum of a stream of mercury acting as a wire in an E.W.P. was studied. The authors attribute the broadening to impact damping and stark effect.

E-126 LANGWORTHY, J. B., O'ROURKE, R. C., SHULER, M. P., VITKOVITSKY, I. M., DOBBIE, C. V., VEITH, R. J., and HANSEN, D. F., "Electrically Exploded Wires - Experiments and Theory," Progress Report I/III/58 to 30/VI/60, NRL Rept. 5489 (1961)

N-6 LAWRENCE, E. O., and DUNNINGTON, F. G., "On the Early Stages of Electric Sparks," Phys. Rev. 35, 396-407 (1930)

P-8 LEJEUNE, J. M., and ROSEN, B., "Recherches sur le spectre d'oxyde de cuivre," Bull. Soc. Roy. Sci., Liege 14, 81 (1945) (Research on the Spectrum of Copper Oxide)

> A wire imbedded in a pile of CuO was "exploded" by 100 amps from a battery and the resulting spectrum analyzed.

P-9 LEJEUNE, J. M., "Applications de la methode d'explosion de fils minces à l'étude du spectre de CaO," Bull. Soc. Roy. Sc., Liege 14, 318-322 (1945) (Applications of the Method of Exploding Wire to the Study of the Spectrum of CaO)

> The spectrum was produced by "exploding" a Cu wire loaded with CaO. Spectra were studied at 100 amp level (intense) and 10 amp level (feeble).

P-10 LOGINOV, V. A., "The Production of Electronic Band Spectra by the Exploding Wire Method," Optika i Spektroskopiya 16, 402-403 (1964), Trans. in Optics and Spectroscopy 14, 220-223 (1964)

Use of E. W. in liquids (H_2O, CCl_4) to produce electronic band spectra (radicals) is described. Results with Al, Ag, Au, Cu and Pt in region from 2400-6000 Å are given.

E-135 LOGINOV, V. A., "Production of the Absorption Spectrum of AlO by the Method of Electrically Exploding a Wire in Air at Atmospheric Pressure," Optika i Spektroskopia 6, 111-113 (1959), Trans in Optics and Spectroscopy 6, 67-68 (1959)

P-11 MALET, L., and ROSEN, B., "Contributions à l'étude du spectre de FeO," Bull. Soc. Roy. Sc. Liege 14, 377-381 (1945), (Contribution to the Study of the FeO Spectrum)

A spectrographic study. The oxide formed in the products of a mild (100A) wire explosion.

P-12 MALET, L., and ROSEN, B., "Étude spectrographique des molecules NiO et CoO," Bull. Soc. Roy. Sc. Liege, 14, 382-389 (1945)

In this study an arc, not an exploding wire was used.

N-7 MARTIN, E. A., "Experimental Investigation of a High-Energy Density, High Pressure Arc Plasma," J. Appl. Phys. 31, 255-267 (1960)

R-7 MAYFIELD, E. B., "Radiometric Temperature Measurements of Exploding Wires," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 147-155

E-143 MEL'NIKOV, M. A., and OBUKHOV, V. I., "Oscillographic Investigation of Electrical Wire Explosions," Izvestiia Vysshikh Uchebnykh Zavedenii, Energetika, 99-102 (1963)

P-13 MENZIES, A. C., "Shifts and Reversals in Fuse-Spectra," Proc. Roy. Soc. (London), A117, 88-100 (1927)

Although the currents used were low (100 amps) this is essentially E. W. P.

P-14 NAGAOKA, H., NUKIYAMA, D., and FUTAGAMI, T., "Instantaneous Spectrograms," (various metals), Proc. Imp. Acad. (Japan) 3, 208-212, 258-264, 319-333, 392-418, 499-502 (1927)

The explosion spectra of many metals are described and illustrated in this series of articles.

P-15 NAGAOKA, H., and FUTAGAMI, T., "Explosion Spectra of Mercury," Proc. Imp. Acad. (Japan) 2, 254-257 (1926)

The authors used two methods: (1) mercuric oxide in carbon electrodes, and (2) exploding a jet of liquid mercury from iron tube. They concluded the second method more like E. W. P.

P-16 NAGAOKA, H., FUTAGAMI, T., and OBATA, H., "Spectra of Metals Excited by Means of High Tension and Heavy Current," Proc. Imp. Acad. (Japan) 2, 161 (1926)

The authors report using explosion spectra to analyze small amounts of materials placed in depressions of carbon electrodes and then exploded. They caution that the spectrum is different from any ordinary spectrum.

U-7 NASH, C. P., DeSIENO, R. P., and OLSEN, C. W., "Electrical and Emissive Properties of Exploded Confined Conductors," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 231-246

E-167 PATERSON, J. E., MURRAY, T. P., and GRIMES, W. F., "Investigations of the Use of an Exploding Wire as a Spectrographic Source," Research Report - Jones and Laughlin Steel Corp., Project 633 T-4 (Jan 1956)

P-17 ROSEN, B., Spectra of Diatomic Oxides by the Method of Exploded Wires," Nature 156, 570-571 (1945)

An announcement of the forthcoming series in the Bull. Soc. Roy. Sci. Liege. Brief mention of line series of FeO, NiO, CaO, CuO, CoO, with promise of more detail in later papers.

E-180 SAWYER, R. A., and BECKER, A. L., "On the Explosion Spectra of the Alkaline Earth Metals," Phys. Rev. 21, 373-(1923)

P-18 SAWYER, R. A., and BECKER, A. L., "The Production of Enhanced Line Spectra by a New Method," Science 54, 305-306 (1921)

Explosion of asbestos threads soaked in a solution of salt.

E-187 SMITH, S., "A Study of Electrically Exploded Wires, Rotating Mirror Spectrograph," Astrophys. J. 61, 186-203 (1925)

E-188 SMITH, S., "Note on Electrically Exploded Wires in High Vacuum," Proc. Nat. Acad. Sci. U.S. 10, 4-5 (1924)

P-19 SPONER, H., "Über Spektren elektrisch zerstäubter Drahte," Naturwissenschaften 12, 619-620 (1924) (The Spectra of Electrically Dispersed Wires.

The author follows Anderson and examines spectra. Attempts to arrange absorption spectra of Bi in a spectrographic scheme. No investigation of the E. W. P. as such.

E-193 STEVENSON, M. J., REUTER, W., BRASLAU, N., SOROKIN, P. P., and LANDON, A. J., "Spectral Characteristics of Exploding Wires for Optical Maser Excitation," J. Appl. Phys. 34, 500-509 (1963)

P-20 TEEPLE, L. R., Jr., "Application of a Time Resolving Spectrograph System," Vi Internat. Congress on High-Speed Photog. (The Hague) (1963) p. 605-612

Discusses design considerations of a time resolved spectrograph, its calibration and limitations. Use of the system is shown on Al exploding wires.

P-21 TRICHE, C., "Étude Spectrographic de l'Emission des Fils Explosés," (Spectrographic Study of Emission from Exploding Wires), J. Chemie Phys. 62, 291-296 (1965)

Copper and iron wires were studied as exploded with a 2000 μF electrolytic bank at 1 kV. Absorption lines, emission lines, continuum, and the unduloid phenomenon were observed.

E-204 TURNER, B. R., "A Study of Exploding Wires," Cal. Tech. Thesis (1960)

E-206 VAUDET, G., "Étude et Emploi d'une Source Lumineuse · Grande Brilliance," Ann. Phys. 9, 645-722 (1938) (The Study and Use of a Light Source of Great Brilliance)

P-22 VAUDET, G., and SERVANT, R., "Spectres de fils explosés dans l'ultraviolet lointain et la region schumann," Compt. rend. 201, 195-197 (1935) (Spectra of Exploded Wires in the Far Ultraviolet and Schumann Region)

Spectra of wires exploded in vacuum were studied in UV and Schumann region. Fe, Cu, Al and Zn were investigated, Al most thoroughly.

A-21 WURSTER, W. H., "High Speed Shutter for Spectrographs," Rev. Sci. Instr. 28, 1093-1094 (1957)

P-23 ZERNOW, L., and HAUVER, G. E., "High Speed Cine-Microscopy and Space-Time Resolved Spectroscopy," High Speed Photography, R. B. Collins (ed), Butterworth, London (1957) p. 305-314

Use of a Beckman and Whitley type camera with microscope objective or a transmission type diffraction grating Results of air shock and metal vapor spectrum are shown.

SWITCHES – Section Q

Q-1 Anon. "5, 000, 000-Ampere Arc," Radio-Electronics 45 (Sept 1960)

A brief description of the Boeing (Seattle) arc driven wind tunnel. Arc is 7 megajoule discharged in few milliseconds. Exploding steel piano wire used as switch to start the arc.

Q-2 BINDER, K., "Die Entwiklung von Schltfunkenstrecken für ein schnells 15 kJ Kondensatorbatterie fur Drahtexplosionen bei 100 kV," (Development of a Spark-gap Switch for a Fast 15 kJ Capacitor Bank for Wire Explosions at 100 kV), in Forschungsbericht K66-27, Bundesminesterium fur wissenschaftliche Forschung (Juli 1966) (Research Report K66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

A spark gap switch for the conditions described in the title is described.

Q-3 BELLASCHI, P. L., "Laboratory Lightning - The Microsecond Switch:" Elect. J 33, 273-275 (1936)

A microsecond switch consists of a length of resistance wire between the current and the voltage generator. The discharge of the voltage generator fuses the wire and establishes an arc path in about 2 microseconds.

Q-4 BROADBENT, T. E., "The Breakdown Mechanism of Certain Triggered Spark Gaps," Brit. J. Appl. Phys. 8, 37-40 (1957)

Investigation of factors determining gap length vs. breakdown voltage. Effect of various methods of triggering on gap behavior.

Q-5 CRAGGS, J. D., HAINE, N. E., and MEEK, J. M., "The Development of Triggered Spark-Gaps for High Power Modulators," Proc. Inst. Elec. Engrs. (London) 93, 3A, 191 (1946)

A discussion of the concentric triggered gap useful for controlling E. W. P.

Q-6 CULLINGTON, E. H., CHACE, W. G., and MORGAN, R. L., "Lovotron - A Low Voltage Triggered Switch Gap," Instrumentation for Geophysical Research, AFCRC-TR-55-227 (Sept 1955)

Description of a concentric triggered gap of low time jitter useful at any voltage down to 2 KV.

X-16 HARRAWAY, R. A., "An Exploding Wire Triggered Spark Gap," J. Sci. Instr. 41, 3?9 (1964)

Q-7 HUBER, H., "Technical Specifications of an Exploding Wire Triggered Solid Dielectric-Switch," Stevens Inst. Tech. SIT P-78 (1/63)

An E.W. is used to puncture a mylar plate and close a switch with an inductance of $<2 \times 10^{-9}$ H. resistance of $<5\times10^{-3}$ ohm.

Q-8 JUDKINS, R. O., "Investigation of a High Current Switch Tube," Sandia Corp. Tech. Memo, Case 628.00 (July 1955) (157-55-51)

Gaseous discharge tube with an inductance of 5 microhenries and a jitter of 5 microseconds. This operates on the principle of storing a supply of electrons above a grid-cathode. Then by driving the electrons through the openings in the grid-cathode to the anode region, the gap is fired.

Q-9 MAISONNIER, C., LINHART, J. G., and GOURLAN, C., "Rapid Transfer of Magnetic Energy by Means of Exploding Foils," Rev. Sci. Instr. 37, 1380-1384 (1966)

Since max di/dt from a capacitor is 10^3 A/sec, it is suggested that energy be stored in a coil. Then need fast opening switch. A cylinder of Al has been so used. Device was built and used to transfer energy originally in 63μF of capacity to a load at 1.5×10^{12} A/sec rise time. Direct discharge is 0.5×10^{12} A/sec. A method of calculating ideal size of exploding switch foil is given.

Q-10 MOSES, K. G., and KORNEFF, T., "The Nonlinear Effects of an Air Gap Switch in Exploding Wire Circuits," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 391-404.

The nonlinear effect found in previous work has been investigated for switches with various electrode metals. The metals used in this series of experiments were steel, copper, and aluminum. The effect of the nonlinearity is to produce an initial current slope of zero and to limit the current rise in the wire during the first quarter-cycle to a value much lower than the current slope predicted by elementary circuit theory. The work reported in this paper shows that the effect is not dependent upon the choice of electrode material, but depends only upon the limitation of the rate of admission of energy into the gap by the initial resistance of the switch. Measurements of the instantaneous energy have shown that approximately 20% of the initial energy stored in the capacitor bank is dissipated by the switch during the first half-cycle of the discharge.

K-10 NORINDER, H., and KARSTEN, O., "Experimental Investigations of Resistance and Power within Artificial Lighthing Current Paths," Ark. Mat. Astron. Fysik 36A, 1-48 (1949)

Q-11 TATIBANA, F., "Triggering Electrical Breakdown in High Vacuum by Wire Explosion," J. Appl. Phys. (Japan) 30, 71-72 (1961)

Discharges 2 to 10 KV on the concentric gap were started by E.W. Used fuse wire, Cu, and Al about 0.25 mm X 25 mm. Distance 25 cm along vacuum tube. Delay of 4-8 microseconds after wire explodes. Mechanism checked by putting glass plate in front of E.W. Explosion only if some opening.

E-206 VAUDET, G., "Étude et Emploi d'une Source Lumineuse de Grande Brilliance," Ann. Phys. 9, 645-722 (1938) (The Study and Use of a Light Source of Great Brilliance)

TEMPERATURE – Section R

E-12 ANDERSON, J. A., "The Spectrum of Electrically Exploded Wires," Astrophys. J. 51, 37-48 (1920)

E-10 ANDERSON, J. A., "The Spectral Distribution and Opacity of Wire Explosion Vapors," Proc. Nat. Acad. Sci. U.S. 8, 231-232 (1922)

W-2 BARTELS, H., GANSAUGE, P., and KUHLMEI, H., "Magnetische Kompression in Gasen Höherer Dichte," V Internat. Conf. on Ionization Phenom. in Gases, Munich, 1961 (Magnetic Compression in Gases at High Densities)

R-1 BEHRENS, W., "Temperatur Bestimmung bei Elektrischen Draht Explosionen," Dis. Hannover 1935, abs Physik Ber. 16 1958 (1935) (Temperature Determination in Electric Wire Explosions)

A consideration of methods of determining temperature in wire explosions.

E-37 BEUCHELT, R., and BÖHM, E., "Über eine Temperatur und Druckmessung im Plasma von Drahtexplosionen," Naturwissenschaften 44, 507 (1957) (Temperature and Pressure Measurement in the Plasma from Exploding Wires)

E-38 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D. Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S.N. Res. Lab. Prog. Rep. 1 Feb - 1 May 1962

N-2 BLOXSOM, D. E., "Production of High Temperature, Moderate Pressure Gases by Means of Electric Spark Discharges," Arnold Eng. Dev. Cent. AEDC-TN-56-17 (1956)

E-54 CHACE, W. G., "The Liquid Behavior of Exploding Wires," Phys. Fluids 2 2[illegible]0-235 (1959)

B-1 COBINE, J. D., and BURGER, E. E., "Analysis of Electrode Phenomena in the High-Current Arc," J. Appl. Phys. 26, 895-900 (1955)

E-71 CONN, W. M., "Metallic Deposits and Shock Waves Due to Electrically 'Exploded' Wires," Phys. Rev. 98, 1551 (1955)

E-69 CONN, W. M., "Studies of the Mechanism of Electrically Exploded Wires," Naturwissenschaften 42, 65-66 (1955)

E-70 CONN, W. M., "Studien zum Mechanismus von electrischen Drahtexplosionen," Z. angew. Physik 7, 539-554 (1955) (Studies on the Mechanism of Electrical Wire Explosions)

R-2 CONN, W. M., "Temperature Its Measurement and Control in Science and Industry," Am. Inst. of Physics, p. 770 Reinhold Pub. Co. (1941)

A short paragraph on E. W. P. as a source of high temperature. Bibliography of 6 references.

E-75 CONN, W. M., "Note on the Polarization of Light Emitted by Electrically Exploded Wires," Phys. Rev. 58, 50-51 (1940)

R-3 CONN, W. M., and DEEG, E. W., "Use of the Solar Furnace as an Intermediate Imaging Source for Attaining Extreme Temperatures for a short Time," Bull. Am. Phys. Soc. 3, 375 (1958)

Abstract of a paper to be given at APS meeting in Chicago November 1958. Combination of E. W. P. and solar furnace. Mentions previous work with E. W. P. and arc image furnace. Abstract gives the impression this is an idea, not an accomplished experiment.

E-76 DAVID, E., "Exploding Wires, Calculation of Heating," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 271-279

E-77 DAVID, E., "Physikalische Vorgänge bei elektrischen Drahtexplosionen," Z. Physik 150, 162-171 (1958) (Physical Processes in Electrical Wire Explosions)

E-78 DAY, P. B., "The Radiant Intensity of Electrically Exploded Wires," J. Opt. Soc. Am. 43, 817 (1953)

N-3 EARLY, H. C., and MARTIN, E. A., "The Underwater Spark, a Photographic Light Source of High Intrinsic Brilliance," Trans. Am. Inst. Elect. Engrs. Pt 1, 44, 788-790 (1955)

R-4 EDELS, H., "The Determination of the Temperatures of an Electrical Discharge in a Gas," The British Electrical and Allied Industries Research Association, Technical Report Reference L/T 230 (1950)

A short discussion (51 pages) of the theory of temperature in a discharge and the methods of measuring and calculating temperature.

E-85 EISELT, B., "Über den Ablauf von Draht Explosionen," Z. Physik 132, 54-71 (1952) (The Course of Wire Explosions)

E-87 ESCHENBACH, R. C., "Measuring Voltage in an Exploded Wire Discharge," Army Project 4A (July 1948)

E-90 FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., VITKOVITSKY, I. M., HARRINGTON, F. D., and McMAHON, J. M., "Exploding Wire Studies," NRL Progress Report 1 May to 1 Aug 1962

N-4 FINKELNBURG, W., "Continuous Electron Radiation in Gas Discharges," Phys. Rev. 45, 341-342 (1934)

E-91 FOURNET, M., "Phénomenes provoqués par des implosions de courant intenses dans des conducteurs résistants," Comptes Rendu 252, 2084-2086 (1961) (Phenomena Produced by Implosions of Heavy Current in Resistive Conductors)

E-92 FUNFER, E., KEILHACKER, M., and LEHNER, G., "Zum Mechanismus von Drahtexplosionen," Z.angew. Physik 10, 157-162 (1959) (On the Mechanisms of Wire Explosions)

E-93 FUTAGAMI, T., "On the Electric Explosion Spectrum of Metals," Sci. Papers Inst. Phys. Chem. Research (Tokyo) 31, 1-29 (1937)

R-5 HERZFELD, C. M., "A Study of Basic Limitations to the Concept and Measurement of Temperature: Incomplete Equilibrium," NBS Report 4420 (Jan 1956)

Discusses the limitations imposed by the system under study, rather than the measuring equipment.

E-101 HERZOG, A., "Influence of Short Time, High Velocity Impact on Materials Structures," Tech. Memo WCRT-56-93, Wright Air Development Center Materials Laboratory (Aug 1956)

Q-8 JUDKINS, R. O., "Investigation of a High Current Switch Tube," Sandia Corp. Tech. Memo, Case 628.00 (July 1955) (157-55-51)

E-119 KUL'GOVCHUCK, V. M., SHISHKIN, Yu. B., BEREZIN, I. A., "Measurement of the Temperature in the First Stage of the Electrical Explosion of Wires," Teplofizika vysokikh temperatur, v 4, No. 3, 419-423 (1966)

R-6 LOCHTE-HOLTGREVEN, W., "Production and Measurement of High Temperatures," Reports Progr. Phys. 21, 312-383 (1958)

Section R

A review article with sections on measurement, production of high temperature. Measurement by observations of continua and line intensities and shapes. Production by arc, pulsed discharges and sparks, E. W.'s, plasma jets and shock waves, chemical reactions.

E-139 MANINGER, R. C., "Preburst Resistance and Temperature of Exploding Wires," U. of Cal. (Livermore) UCRL-7613 (1964)

N-8 MARTIN, E. A., "The Underwater Spark: An Example of Gaseous Conduction at about 10,000 Atmospheres, Univ. of Michigan 2048-12-F (July 1956)

R-7 MAYFIELD, E. B., "Radiometric Temperature Measurements of Exploding Wires," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959), p. 147-155

Use of four color spectrograph monitored by photoelectric cells to determine temperature using Wien radiation equation. Unusually low temperatures around 4000°K were found.

R-8 PREINING, O., "Laboratoriumsmassige Herstellung von hohen Temperaturen (bis 55,000°)," Osterreichische Chemiker-Zeitung 55, 67-72 (1954) (Production of High Temperatures (up to 55,000°) in the laboratory)

Describes two types (1) short period and (2) continuous. (1) Nuclear explosions, explosions, E. W. P., hi-power sparks, (2) continuous-arcs, water stabilized arcs. Brief mention of theory of temperature and of methods of measurement.

R-9 ROUSE, C. A., "Lower-Upper Bounds of Temperatures for Wires Exploded in a Vacuum," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 33-35

Results of a preliminary attempt to establish lower-upper bounds on exploding wire temperatures. The maximum blackbody temperatures for wires exploded in vacuum were found to be limited by hydrodynamics, radiation and ionization.

R-10 SAHA, M. N., "On the Problem of Temperature Radiation of Gases," Phil. Mag. 41, 267-278 (1921)

Examines the status of the problem at the time of the article and suggests methods of attack. Does not arrive at an answer.

E-183 SCHERRER, V. E., " The NRL-AFSWP Exploded Wire Research Program," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 118-134

R-11 SHERK, P. M., "Temperatures of Plasmas Produced by Exploding Wires under Water," Phys. Fluids 7, 913-915 (1964)

The author measured brightness temperature of E. W. 2 mils × 2. 2 mm long under water. He found a straight line relation between the max brightness temperature and ionization potential for the wires tested (Al, Cu, W, Pt). Maximum brightness was at 5017 Å

R-12 VANYUKOV, M. P., and MAK, A. A., "High-Intensity Pulsed Light Sources," Uspekhi Fiz. Nauk. 66, 301-329 (1958), Trans in Soviet Physics Uspekhi 66, 137-155 (1958)

Discusses: Spark discharge in gases, spark discharges in capillaries, gliding spark discharge, electric explosion of wires and shock waves. A section on measuring brightness and temperature of pulsed light sources. Brightness determined by photographic and photoelectric methods. A discussion of the various methods available for measuring temperature in discharges lasting only 10^{-7} sec.

E-206 VAUDET, G., "Étude et Emploi d'une Source Lumineuse de Grande Brillance," Ann. Phys. 9, 645-722 (1938) (The Study and Use of a Light Source of Great Brilliance)

E-208 WEBB, F., "Study of Electrically Exploded Wire Materials," ESO Report 210- QL-7 (May 1960), Electro-Optical Systems, Inc., Quarterly Progress Report.

E-215 WILSON, R., "The Infrared Spectral Radiant Intensity of Exploding Wires," U.S.N. Ord. Test Stn. NOTS TP 2697 (1961)

THEORY – Section S

E-6 ALLEN, W. A., HENDRICKS, C. H., MAYFIELD, E. B., and MILLER, F. M., "Electronic Shutter Photographs of Exploding Bridge Wires," Rev. Sci. Instr. 24, 1068-1069 (1953)

E-10 ANDERSON, J. A., "The Spectral Distribution and Opacity of Wire Explosion Vapors," Proc. Nat. Acad. Sci. U.S. 8, 231-232 (1922)

E-11 ANDERSON, J. A., "Spectra of Explosions," Proc. Nat. Acad. Sci. U.S. 6, 42-43 (1920)

E-12 ANDERSON, J. A., "The Spectrum of Electrically Exploded Wires," Astrophys. J. 51, 37-48 (1920)

E-13 ANDERSON, J. A., and SMITH, S., "General Characteristics of Electrically Exploded Wires," Astrophys. J. 64, 295-314 (1926)

Section S

E-20 BAXTER, H. W., Electric Fuses, Edward Arnold, London (1950)

R-1 BEHRENS, W., "Temperatur Bestimmung bei Elektrischen Draht Explosionen," Dis. Hannover, abs. in Physik Ber. 16, 1958 (1935) (Temperature Determination in Electric Wire Explosions)

E-21 BENNETT, F. D., "Nonlinear Equations for Circuits Containing Exploding Wires," Phys. of Fluids 9, 471-477 (1966)

E-22 BENNETT, F. D., "High Temperature Cores in Exploding Wires," Phys. of Fluids 8, 1106-1108 (1965)

E-23 BENNETT, F. D., "Initial Heating Rates and Energy Inputs for Exploding Wires," Phys. of Fluids 7, 147-148 (1964)

E-36 BETHGE, O., "Mechanische Verformungen durch electrische Engladungen," Ann. Physik 8, 475-499 (1931) (Mechanical Distortions due to Electrical Discharges)

E-41 BRAUN, F., "Der Mechanismus der electrischen Zerstäubung, Schmelzen von Kohlenstoff; Zerlegung von Metallegierungen," Ann. Physik 17, 359-363 (1905) (The Mechanism of Electrical Sputtering; Fusion of Carbon; Segregation of Alloys)

E-54 CHACE, W. G., "The Liquid Behavior of Exploding Wires," Phys. Fluids 2, 230-235 (1959)

E-65 COFFMAN, M. L., "The First Picosecond in an Exploding Wire," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 89-102

E-71 CONN, W. M., "Metallic Deposits and Shock Waves Due to Electrically 'Exploded' Wires," Phys. Rev. 98, 1551 (1955)

E-69 CONN, W. M., "Studies of the Mechanism of Electrically Exploded Wires," Naturwissenschaften 42, 65-66 (1955)

E-70 CONN, W. M., "Studien zum Mechanismus von electrischen Drahtexplosionen," Z. angew. Physik 7, 539-554 (1955) (Studies on the Mechanism of Electrical Wire Explosions)

E-72 CONN, W. M., "A New Effect Observed in Connection with Electrically 'Exploded' Wires," Nature 169, 150 (1952)

E-75 CONN, W. M., "Note on the Polarization of Light Emitted by Electrically 'Exploded' Wires," Phys. Rev. 58, 50-51 (1940)

E-76 DAVID, E., "Exploding Wires, Calculation of Heating," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 271-279

E-77 DAVID, E., "Physikalische Vorgänge bei elektrischen Drahtexplosionen," Z. Physik 150, 162-171 (1958) (Physical Processes in Electrical Wire Explosions)

E-85 EISELT, B., "Über den Ablauf von Draht explosionen," Z. Physik 132, 54-71 (1952) (The Course of Wire Explosions)

E-87 ESCHENBACH, R. C., "Measuring Voltage in an Exploded Wire Discharge," Army Project 4A (July 1948)

N-4 FINKELNBURG, W., "Continuous Electron Radiation in Gas Discharges," Phys. Rev. 45, 341-342 (1934)

E-92 FÜNFER, E., KEILHACKER, M., and LEHNER, G., "Zum Mechanismus von Drahtexplosionen," Z. angew. Physik 10, 157-162 (1959) (On the Mechanism of Wire Explosions)

S-1 GELDMACHER, R. C., "Recent Contributions to the Macroscopic Analysis of Conducting Electromechanical Solids," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 15-20

The behavior of conducting solids subjected to strong electric fields has been recently investigated analytically by both Haines and Geldmacher. In this paper the general formulation of the problem is presented and the solutions and results of the two authors are reviewed and discussed. The mechanical breakup mechanisms given by the two authors are entirely different and it is suggested that the actual breakup may be explained in terms of a combination of the two mechanisms.

C-2 HERING, C., "Revision of Some of the Electromagnetic Laws," J. Franklin Inst. 192, 599-622 (1921)

E-111 KEILHACKER, M., "Über den Mechanismus der explosions-artigen Verdampfung von Kupferdrähten durch sher intensive Stromstösse und das Verhalten des Kupfers bei den dabei auftretenden hohen Drucken und Temperauten," Z. angew. Physik 12, 49-59 (1960) (On the Mechanism of Explosive Vaporization of Copper Wires by Very Large Current Pulses and the Behavior of Copper at the Resulting High Pressures and Temperatures)

E-114 KLEEN, W., "Über den Durchgang der Elektrizität durch metallische Haardrähte," Ann. Physik 11, 579-605 (1931) (On the Passage of Electricity thru Fine Metal Wires)

S-2 KLUGE, W., and HOCKER, K. H., "Ohmic Heating of Fully Ionized Plasmas," Proc. of the Fourth International Conference on Ionization Phenomena in Gases, Vol. II, N. R. Nilsson (ed), North-Holland Pub. Co., Amsterdam (1960)

Condenser discharge across whirl-stablized arc. No pinch, no skin effect, no "E.W." behavior was discovered. Current rose instantaneously to 10^5 amps from 10^2 A. Phenomenon was studied by oscillograms of I(t) di/dt, E(t), and with image converter photos of the expanding arc column. Ohmic heating was the simple explanation of all observed data. (This indicates that E.W. phenomena do not occur in the plasma, but in the still condensed phase material).

E-120 KVARTSKHAVA, I. F., "Concerning Papers of E.S. Khaikin, S. V. Lebedev and B. N. Borodovskia Published in the Zhur. Eksp. i Teoret. Fiz. in 1954-1955," Zhur. Eksp i Teoret. Fiz. 30, 621 (1957); Soviet Phys. JETP 3, 787 (1956)

E-122 KVARTSKHAVA, I. F., BONDARENKO, V. V., PLIUTTO, A. A., and CHERNOV, A. A., "Oscillographic Determination of Energy of Electric Explosion of Wires," Zhur. Eksp. i Teoret. Fiz. 31, 745-751 (1956); Soviet Phys. JETP 4, 623-629 (1957)

E-124 KVARTSKHAVA, I. F., PLIUTTO, A. A., CHERNOV, A. A., and BONDARENKO, V. V., "Electrical Explosion of Metal Wires," Zhur. Eksp. i Teoret. Fiz. 30, 42-53 (1956) Soviet Phys. JETP 3, 40-51 (1956)

U-6 LANGBERG, E., "Analysis of Exploding Foil Process," Avco Corp. RAD-TN-65-40 (1965)

E-126 LANGWORTHY, J. B., O'ROURKE, R. C., SHULER, M. P., VITKOVITSKY, I. M., DOBBIE, C. V., VEITH, R. J., and HANSEN, D. F., "Electrically Exploded Wires - Experiments and Theory," NRL Report 5489 (1961)

E-127 LAPPLE, H., Electric Fuses, A Critical Review of Published Information, Butterworth, London (1952)

K-7 LEBEDEV, S. V., and KHAIKIN, S. E., "Some Anomalies in the Behavior of Metals Heated by Current Pulses of Great Density," Zhur. Eksp. i Teoret. Fiz. 26, 629-639 (1954)

E-130 LEBEDEV, S. V., "Explosion of a Metal Due to an Electric Current," Zhur. Eksp. i Teoret. Fiz. 32, 199-207 (1957) Soviet Phys. JETP 5, 243-252 (1957)

E-131 LEBEDEV, S. V., "Phenomena in Tungsten Wires Preceding Their Disintegration Under the Effects of Heavy Current," Zhur. Eksp. i Teoret. Fiz. 27, 605-614 (1954)

S-3 MANINGER, R. C., "Effects of Transmission Lines in Applications of Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 109-126

The effects of transmission line behavior of circuits on current, voltage, and energy transfer are treated in this paper by finding the transient solutions of the transmission line equations. In general cases, the solutions are multiple summation series requiring considerable numerical computation for comparison with experimental results. Fortunately, in most applications the solutions are simple staircase functions. These predict circuit behavior within a few percent of observations. A number of rules of thumb have been devised for use in estimating the degree of importance of transmission line effects in any given exploding wire circuit.

E-139 MANINGER, R. C., "Preburst Resistance and Temperature of Exploding Wires," U. of Cal. (Livermore) UCRL-7613 (1964)

K-9 MARGENAU, H., "Die Abweichungen vom Ohmeschen Gasetz bei hohen Stromdichten im Lichte der Sommerfieldschen, Elektronentheorie," Z. Physik 56, 259-261 (1929) (The Deviation from Ohm's Law at High Current Density in the Light of Sommerfeld's Electron Theory)

S-4 MEEKER, M. E., "Solid and Solid-Liquid Phases in Wires at High Current Densities," Sandia Tech. Memo SCTM 314-58 (51) (1958)

Study of thermodynamic and energy balance in an E. W. up to the point of complete melting. Studies were made of losses and of pressures both magnetic and inertial. Energy to reach Curie point was discussed.

E-146 MOSES, K. G., and KORNEFF, T., "The Application of P.W. Bridgman's 'New emf' to Exploding Wire Phenomena," Exploding Wires, Vol. III, Chace and Moore (eds), Plenum Press, New York (1964) p. 37-46

E-151 NAGAOKA, H., and FUTAGAMI, T., "Cinematographic Sketch of Electrically Exploded Wires," Proc. Imp. Acad. (Japan) 4, 198-199 (1928)

E-152 NAGAOKA, H., and FUTAGAMI, T., "Electric Explosion in Magnetic Field," Proc. Imp. Acad. (Japan) 4, 283 (1928)

E-157 NASH, C. P., and McMILLAN, W. G., "On the Mechanism of Exploding Wires," Phys. Fluids 4, 911-917 (1961)

E-158 NASH, C. P., and OLSEN, C. W., "Initial Phase of the Exploding Wire Phenomenon," Phys. of Fluids 7, 209-213 (1964)

S-5 O'KEEFE, J. D., and SCULLY, C. N., "Axial Flow From a Radially Confined Electrically Exploded Cylinder," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 211-222

The case of axial flow from the end of a metallic cylinder bounded by an insulating wall under capacitor discharge conditions has been studied both theoretically and experimentally. Flow parameters for the resulting dense plasma were formulated in terms of experimentally observed energy input rates. Two formulations are given, a quasi-steady approximation and one employing one-dimensional unsteady hydrodynamic equations in Eulerian form. Computations were carried out for various metallic elements, cylinder dimensions, and constraining geometry. Results indicated that for an input energy of 21,300 J into a lithium cylinder of 1.5 by 25 mm dimensions flow velocities were greater than 20 km/sec and densities greater than 0.1 g/cc for times up to 5 μsec. Experimental confirmation of the computed values were obtained by flow-velocity measurements obtained from velocity measurements of micron-diameter ceramic spheres accelerated by fluid-dynamic drag in the fluxing plasma.

S-6 PLATEAU, J., "The Figures of Equilibrium of a Liquid Mass Withdrawn from the Action of Gravity," Ann. Rep. Smithsonian Inst. 18, 207-285 (1865) ibid 19, 285-369 (1865), ibid 20, 411-435 (1866), ibid 21, 256-289 (1867)

Exhaustive discussion of the stability of various liquid shapes, p. 207-285 (1864) discussed matters which led to the development of the unduloid theory of Kleen.

M-20 ROUSE, C. A., "Theoretical Analysis of the Hydrodynamic Flow in Exploding Wire Phenomena." U. of Cal (Livermore) UCRL-5519-T (1959)

E-169 PORTER, H. L., "The Electric Fusion of Fine Wires," Armament Research Establishment Report 1/53 (1953), Ministry of Supply, Adelphi, London w.c. 2

E-178 RUTHERFORD, E., "Disintegration of Elements," Nature 109, 418 (1922)

E-181 SAWYER, R. A., and BECKER, A. L., "The Explosion Spectra of the Alkaline Earth Metals," Astrophys. J. 57, 98-113 (1923)

K-12 SHABANSKII, V. P., "On Deviations from Ohm's Law in Metals," Zhur. Eksp. i Teoret. Fiz. 27, 147-155 (1954)

E-187 SMITH, S., "A Study of Electrically Exploded Wires, Rotating Mirror Spectrograph," Astrophys. J. 61, 186-203 (1925)

E-189 SOBOLEV, N. N., "Investigation of the Electrical Fusion of Thin Wires," Zhur. Eksp. i Teoret. Fiz. 17, 986-997 (1947)

E-197 THOMPSON, J. J., "Analysis by Positive Rays of the Heavier Constituents of the Atmosphere, of the Gases in a Vessel in which Radium Chloride had been Stored for Thirteen Years and of the Gases Given Off by Deflagrated Metals," Proc. Roy. Soc. (London) 101A, 290-299 (1922)

S-7 TIMOFEEVA, G. G., "Pinch Effect and Breaking of the Arc in the Constriction," Zh. Techn. Fiz. 27, 2669-2671 (1957) (Trans. in Soviet Physics-Tech. Phys. 2, 2480-2481 (1957)

Concerns a low-pressure discharge through a constriction. Formulas are given for critical breaking current and current for no break which is greater than critical. A value for pressure above which no break can occur is also given.

E-206 VAUDET, G., "Étude et Emploi d'une Source Lumineuse de Grande Brilliance," Ann. Phys. 9, 645-722 (1938) (Study and Use of a Light Source of Great Brilliance)

E-209 WEBB, F., "Study of Electrically Exploded Wire Materials," Electro-Optical Systems Report 210-QL-4 (1959)

S-8 WEBB, F. H., Jr., HILTON, H. H., LEVINE, P. H., and TOLLESTRUP, A. V., "Exploring the Nature of Bridgewire Explosions," Space/Aeronautics 75-80 (Aug 1962)

E-217 WRANA, J., (Abstract of E-218), Phys. Ber. 21, 522 (1940)

E-218 WRANA, J., "Vorgänge beim Schmeilzen and Verdampfen von Drähten mit sehr hochen Stromdichten," Arch. Electrotechnik 33, 656-672 (1939) (Processes in the Melting and Vaporization of Wires with Very High Current Densities)

E-219 WRANA, J., "Vorgänge in Sicherungen bei elektrischer Stossbelastung," Electrotech Z. 59, 11-13 (1938) (Processes in Fuses Subjected to Surge Currents)

E-220 ZAREM, A. M., MARSHALL, F. R., and POOLE, F. L., "Transient Electrical Discharges: Disintegration of Small Wires," Phys. Rev. 72, 158 (1947)

E-3 ABRAMOVA, K. B., VALITSKII, V. P., VANDAKUROV, Yu. V., ZLATIN, N. A., and PEREGUD, B. P., "Magnetohydrodynamic Instabilities in an Electrical Explosion," Dokl. Akad. Nauk SSSR 167, 778-781 (1966) (Trans. in Soviet Physics, Doklady 11301-304 (1966)

E-4 ABRAMOVA, K. B., VALITSKII, V. P., VANDAKUROV, Yu. V., and PEREGUD, B. P., "Magnetohydrodynamical Instabilities in Electrical Explosion," Phys. Letters (Netherlands) 18, 286-288 (1965)

E-17 BARKOW, A. G., KARIORIS, F. G., and STOFFELS, J. J., "X-ray Diffraction Analysis of Aerosols from Exploding Wires," Advances in X-ray Analysis, VI, Plenum Press, New York (1963) p. 210-222

E-39 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S. Naval Res. Lab. Progress Report (Nov 61 - Feb 62)

T-1 BEY, P. P., FAUST, W. R., FULPER, R., HARRINGTON, F. D., LEAVITT, G. E., SHIPMAN, J. D., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S. Naval Res. Lab. Progress Report (Aug - Nov 1961)

Describes measurement of X-rays from wires with absorbers and photomultipliers studying directional uniformity. Time resolved spectra of imploding Al cylinder. Also describes their new voltage measuring system. Results of new mylar capacitor.

E-38 BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., SHIPMAN, J. D., Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," U.S.N. Res. Lab. Prog. Rep. (1 Feb - 1 May 1962)

A-6 BREIDENBACH, H. I., Jr., "A Fractional Microsecond X-ray Pulse Generator Studying High Explosive Phenomena," Rev. Sci. Instr. 20, 899-903 (1949)

E-46 CHACE, W. G., "Use of X-rays in Exploding Wire Studies," Bull. Am. Phys. Soc. 10, 166 (1965)

E-89 FAUST, W. R., LEAVITT, G. E., SHIPMAN, J. D., Jr., and VITKOVITSKY, I. M., "Exploding Wire Studies," NRL Prog. Rept. (1 Aug to 1 Nov 1962)

E-97 GORDIENKO, V. P., and SHNEERSON, G. A., "Electrical Explosion of Skin Layer," Zh. Tek. Fiz. 34, 376-378 (1964)

T-2 HÄNDEL, S. K., STENERHAG, B., and HOLMSTRÖM, I., "Hard X-rays from Exploding Wires," Nature 209, 1227-1228 (1966)

Using a plastic scintillator and photomultiplier X-rays were detected from the explosion of 0.07 mm (~No. 40) 33 mm long W wire at 20kV The x radiation comes from about 14 Kev electrons.

X-23 KARIORIS, F. G., and WOYCI, J. J., "X-Ray Investigation of Aerosols from Wires Exploded in Nitrogen," Proc. Twelfth Ann. Conf. on Appl. of X-ray Analysis (Aug 1963) p. 240-251

E-118 KUL'GAVCHUK, V. M., and NOVOSKOL'TSEVA, G. A., "X-Ray Study of Kinetics of Heating and Evaporation of Exploding Wires," Zh. Tek. Fiz. 36, 549-556 (1966) (Trans. in Soviet Physics-Tech. Phys. 11, 406-412 (1966)

T-3 MILLER, S. W., and SHOENS, C. J., "Sub-Microsecond X-ray Unit for Explosives Research," Poulter Labs. Tech. Report 002-55, Stanford Research Institute (June 1955)

Description of a narrow beam flash X-ray unit, suitable for explosive, hence E.W.P. studies.

T-4 PASZEK, J. J., TAYLOR, B. C., and SQUIER, J. L., "Low Voltage Flash Radiography," BRL Report 645 (Feb 1953)

Detailed description of flash radiography equipment. Types of tubes suitable are discussed and compared.

E-182 SCHAAFS, W., "Beobachtungen an Elektricshen Drahtexplosionen," Z. angew. Physik 11, 63-65 (1959) (Observations on Wire Explosions)

M-23 SCHALL, R., and THOMER, G., "Röntgenblitz aufnahmen von Stosswellen in festen, flussigen und gasformigen Median," Z. angew. Physik 3, 41-44 (1951) (X-ray Flash Photographs of Shock Waves in Solid, Liquid and Gaseous Media)

T-5 SLACK, C. M., and DICKSON, D. C., "One-Millionth-Second Radiograph and Its Applications," Proc. Inst. Radio Engrs, 35, 600-606 (1947)

Description of equipment. Bibliography.

E-207 VITKOVITSKY, I. M., "X-ray Emission from Exploding Wires," Phys. Fluids 7 612-613 (1964)

T-6 VITKOVITSKY, I. M., BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., and SHIPMAN, J. D., Jr., "Exploding Wires as a Source of X-rays," Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 87-96

A discussion of methods of producing x-rays by exploding conductors (tubes), methods of observing, and some characteristics of the

emitted radiation. The relation of electrical characteristics of the conductors to the emitted rays is also included.

EXPLODING FOILS AND FILMS – Section U

U-1 ANON., "Metallic Vapor Plasma: Future Propellant?" Electronics, Aug 18, 1961, p. 20-21

A description of work being done to study exploding films and wires as propulsion devices. Brief general statement about wire explosions in general.

U-2 CNARE, E. C., "Observations on the Striations of Electrically Exploded Copper Foils," J. Appl. Phys. 32, 1043-1044 (1961)

The author reports peculiar, regular striations consisting of alternately "cold" and "hot" regions across a thin foil when exploded at 20 KV. Arcs which seem to be the result of the striations occur along the edges. Only high conductivity materials, Cu, Ag and Al exhibit striations. Spacing is dependent only on foil thickness.

M-7 DENNEN, R. S., and WILSON, L. N., "Electrical Generation of Imploding Shock Waves," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 145-157

F-2 FISH, C. V., and CHACE, W. G., "Uniform Light from Exploding Conductor," Rev. Sci. Instr. 37, 1401 (1966)

X-17 GUENTHER, A. H., WUNSCH, D. C., and SOAPES, T. D., "Acceleration of Thin Plates by Exploding Foil Techniques," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 279-298

U-3 GUENTHER, A. H., "Production of Strong Shocks in Plastics by Ultra-Short Impulsive Loading," Air Force Special Weapons Lab. AFSWC - TDR-62-125 (1962)

Pressures in excess of 100 kb can be produced in plastics by the impact of high velocity thin plates. These plates, mainly Mylar and Lucite in the range of 10^{-2} to 0.6 cm in thickness and areal dimensions to 7.5 cm square, have been accelerated by an exploding foil technique. Plates impacted at velocities approaching 5×10^5 cm/sec have been used for the study of material dynamics at high transient pressures. Pulse lengths in the submicrosecond-to-few-microsecond region can be produced by this technique, and the variation of the strength of materials with pulse length can be determined. A description of the technique and methods for analyzing the data are presented, including an explanation of the construction of the transducer and photographic equipment used in the laboratory for the velocity determination. Various applications of this technique are also given.

U-4 KATZENSTEIN, J., "Electric Discharge Through Small Conductors," Univ. of New Mexico Tech. Report (Sept 1960)

Polyethylene filaments were coated with graphite and exploded. Shots were carried out in a vacuum of 10^{-5} mm Hg, and photographed from the end with a streak camera. Current determined by a Rogowski coil and voltage with a resistive divider. Author finds divider unreliable. The polyethylene filaments show irregular multiple expansions after a very long constrained period (up to 3μsec). There is no explanation of these phenomena.

X-25 KELLER, D. V., and PENNING, J. R., Jr., "Exploding Foils - The Production of Plane Shock Waves and the Acceleration of Thin Plates," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 263-277

U-5 KELLER, D. V., and TRULIO, J. G., "Mechanism of Spall in Lucite," J. Appl. Phys. 34, 172-175 (1963)

Exploding foils are used to produce impact and one dimensional shock in lucite. Free rise of 1/16 inch in vacuum 50 μ Hg was allowed. Driver velocity, measured by pin technique reached 2.2×10^3 m/sec.

No data on the electrical circuit to explode the foil.

U-6 LANGBERG, E., "Analysis of Exploding Foil Process," Avco Corp - RAD-TN-65-40 (1965)

Metal explosion is considered from thermodynamic point of view. The dynamic behavior of atomic separation in the exploding foil is also considered in detail and the results of an analog computer simulation of the explosion are compared with the experimental results.

Q-9 MAISONNIER, C., LINHART, J. G., and GOURLAN, C., "Rapid Transfer of Magnetic Energy by Means of Exploding Foils," Rev. Sci. Instr. 37, 1380-1384 (1966)

U-7 NASH, C. P., DeSIENO, R. P., and OLSEN, C. W., "Electrical and Emissive Properties of Exploded Confined Conductors," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 231-246

The explosion in air of internally silvered Pyrex or quartz tubes is characterized by a (virtually) exponential decay of the condenser voltage with time, whereas the restrike phase of an unconfined exploding wire is oscillatory. The emission spectra of silvered tubes show only an intense continuum, apart from a very few reversals. When wires threaded axially within Pyrex or quartz tubes are exploded in air, a "leaky" pause is observed, the duration of which varies with the tube diameter. The restrike portion of the oscillograms for wires exploded in 1 mm tubes (long pause) show mostly line emission with only a faint

continuum. The spectra of wires exploded in 8 mm tubes (abnormally short pause) show essentially a pure continuum, with a few reversals. Photographs of these latter samples show that restrike occurs between the tube wall and the wire vapor perimeter. It is suggested that a major contributor to the continuum is an interaction between the discharge and the tube wall for either axial wires or silvered tubes.

U-8 SCHENK, G., and LINHART, J. G., "Compression of Magnetic Fields by Exploding Foils," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 223-230.

Experiments are described in which a thin cylindrical metallic foil is exploded by passing a pulse of electrical current through it. The plasma generated in such an explosion compresses an axial magnetic field. Initial fields of several kilogauss have been thus compressed to about 60 kG. Interpretation of the details of the explosion and compression processes is attempted.

X-33 SCHERRER, V. E., "An Exploding Wire Hypervelocity Projector," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 235-244.

X-34 SCHERRER, V., "Effects of Hypervelocity Impacts on Materials," Tech. Doc. Rept. No. ASD-TDR-62-762 (Aug 1962)

X-35 SCHIFF, D., "Bonding Experiments with Exploding Foils," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 283-287

J-17 THEOPHANIS, G. A., "A Kerr-Cell Camera with Synchronized Light Source for Millimicrosecond Reflected Light Photography," V Internat. Congress on High-Speed Photog., Washington, p. 129-134 (1960)

E-207 VITKOVITSKY, I. M., "X-ray Emission from Exploding Wires," Phys. Fluids 7, 612-613 (1964)

T-6 VITKOVITSKY, I. M., BEY, P. P., FAUST, W. R., FULPER, R., Jr., LEAVITT, G. E., and SHIPMAN, J. D., Jr., "Exploding Wires as a Source of X-rays," Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 87-96

U-9 WOFFINDEN, G. J., "Exploding Metal Films," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 193-210

Vacuum evaporated films of Al, Sn, Cu, Ni, and Fe were electrically exploded by the discharge current from a high-voltage capacitor. Three film thicknesses were investigated on substrates of glass and plexiglass at various energy levels in the range from 1 to 10 J. Results of current and voltage measurements made with coaxial shunts and photographic observations made with a high-speed framing camera are presented.

U-10 WUNSCH, D. C., SOAPES, T. D., and GUENTHER, A. H., "Acceleration of Thin Plates by Exploding Foil Techniques," Air Force Special Weapons Lab Report AFSWC-TDR-61-75 (Jan 1962)

A technique for the acceleration of thin plates to high velocities by exploding foils has been developed. The plates, primarily Mylar and Lucite are used to produce a high-impulse, short-time loading of materials. Velocities up to 5×10^5 cm/sec have been achieved. A brief description of equipment including the capacitor system, cameras, backlighting, etc., is given.

U-11 ZERNOW, L., and WOFFINDEN, G., "Cinemicrographic Study of Electrically Exploded Metal Foils," VI Internat. Congress on High-Speed Photog., The Hague (1963), p. 206-216

Studies of W and Mo foils 0.3×40 mils and 1/2 inch long. A 2 μF condenser and various voltages were used. Transverse striation appear in all experiments. Recording was by self luminosity and framing rate about 0.5×10^6 frames/sec.

U-12 ZERNOW, L., WRIGHT, F., Jr., and WOFFINDEN, G., "High-Speed Cinemicrographic Studies of Electrically Exploded Metal Films," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press (1962) p. 245-262

Exploding films exhibit a striation phenomenon previously reported. Studies of exploding films of Al on glass substrate indicate that these striations are essentially perpendicular to the current path and result early in the discharge.

More detailed studies of these striations have been made.

PLASMAS – Section W

E-4 ABRAMOVA, K. B., VALITSKY, V. P., VANDAKUROV, Yu. V., ZLATIN, N. A., and PEREGOOD, B. P., "Magnetohydrodynamic instabilities in Electrical Explosion," Private Communication (1965)

X-1 ANON., "Metallic Vapor Plasma: Future Propellant," Electronics 34, 20-21 (Aug 1961)

W-1 AYCOBERRY, C., BRIN, A., DELOBEAU, F., and VEYRIE, P., "Striction de Plasmas Metalliques Obtenus Par Explosions de Fils," V. Internat. Conf. Ionization Phenom. in Gases, Munich, 1961, Vol. I, p. 1052-1059. (Pinch in Metallic Plasmas Obtained from Wire Explosions)

Cu wires exploded at 5 kJ, 100 kV in coax geometry and pressure of 3×10^{-6} Torr. Measured E and I and took photos showing a pinch, L of the wire vapor was calculated from d/dt (Li) and from the geometry of the column. The energy balance shows the plasma furnishing energy to the field up to 0.5 μsec then visa versa. Temp

was calculated by combining Bennett's eq. with the Saha. The result was 75,000°K. Most of the energy goes into ionization, not into raising the temperature.

W-2 BARTELS, H., GANSAUGE, P., and KUHLMEI, H., "Magnetische Kompression in Gasen Hoher Dichte," V Internat. Conf. on Ionization Phenom. in Gases, Munich, 1961, 2032-2033 (Magnetic Compression in Gases at High Densities)

An E.W. discharge is further stressed by discharging a large (400 μF, 30 kV) bank through its plasma, immediately it is formed. A strong compression "pinch" results. Spectrographic temperature 70,000°K.

E-25 BENNETT, F. D., "Shock Producing Mechanisms for Exploding Wires," BRL Report 1161 (Feb 1962)

E-26 BENNETT, F. D., "Shock-Producing Mechanisms for Exploding Wires," Phys. of Fluids 5, 891-898 (1962)

E-46 CHACE, W. G., "Use of X-rays in Exploding Wire Studies," Bull. Am. Phys. Soc. 10 166 (1965)

E-52 CHACE, W. G., "Observations in High Density Plasmas Produced by Exploding Wires," Proceedings of the Fourth International Conference on Ionization Phenomena in Gases, Vol. II, pp. IVE1191 - IVE1195, N. R. Nilsson (ed), North-Holland Pub. Co., Amsterdam (1960)

E-108 KATZENSTEIN, J., "The Exploding Wire as Fast Dynamic Pinch," Univ. of New Mexico Final Tech. Report (July 1961)

E-110 KATZENSTEIN, J., and SYDOR, M., "Exploding Wire as Fast Dynamic Pinch," J. Appl. Phys. 33, 718-723 (1962)

W-3 LEIGH, C. H., "Exploratory Research on the Vaporization of Solids," AVCO, Res. and Adv. Develop. Div. Tech. Report RAD-TR-62-19 (1962)

A wire was exploded in a time-of-flight spectrometer, serving thus as a plasma source and high temperature source for study of vaporization products. Coatings on the wires were studied. A train of metallic Ag powder mixed with silica powder and the material under study was also "exploded" as a plasma source.

K-8 MANKA, C. K., and ZINKE, O. H., "Observed Dwells in Current through a Pulsed Argon Plasma," Phys. of Fluids 8, 1186 (1965)

N-7 MARTIN, E. A., "Experimental Investigation of a High-Energy Density High-Pressure Arc Plasma," J. Appl. Phys. 31, 255-267 (1960)

E-140 MEDVED, D. B., and TURNBULL, W., "Microwave Absorption of Exploding Wire Plasmas," Bull. Am. Phys. Soc. 7, 441 (1962)

W-4 ROSEBROCK, T. L., "Study of Plasma Mass-Velocity Distribution in a Pulsed Electromagnetic Accelerator," Allison Division, General Motors Corp. EDR 2736 (Aug 1962)

Results of an analog computer study of the plasma dispersion in a wire explosion were used to study the rail accelerator behavior. Typical plasma trajectories are given graphically.

U-8 SCHENK, G., and LINHART, J. G., "Compression of Magnetic Fields by Exploding Foils," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 223-230.

E-184 SEYKORA, E. J., "Magnetic Mirror Confinement of Exploding Wire Plasma," Nature 191, 995-996 (1961)

R-12 SHERK, P. M., "Temperatures of Plasmas Produced by Exploding Wires under Water," Phys. Fluids 7, 913-915 (1964)

X-37 STARR, W. L., "Exploding Wire Plasma Accelerator," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 365-373

E-191 STARR, W. L., "Impulse from an Exploding Wire Plasma Accelerator," J. Appl. Phys. 30, 594-595 (1959)

E-192 STARR, W. L., and NAFF, J. T., "Acceleration of Metal Derived Plasmas," Lockheed Tech. Memo LMSD-288240 (Dec 1959)

USES – Section X

X-1 ANON., "Metallic Vapor Plasma: Future Propellant," Electronics 34, 20-21, (Aug 18, 1961)

News release about Webb's work on wires and films.

Q-1 ANON., "5,000,000-Ampere Arc.," Radio Electronics, 45 (Sept 1960)

E-2 ANON., "Statement on Electro-Optical Systems Work for Army," Missile Design and Development 7, (Mar 1960)

X-2 ANDREEV, S. I., and VANYUKOV, M. P., "Use of Electrical Explosion of Wires to Produce Ultra-Short Light Flashes," Zh. Techn. Fiz 34, 187_-1872 (1964), Trans. in Soviet Physics-Tech. Phys. 9, 1443-1444 (1965)

The wire is used as a switch to interrupt current in the light-producing gap. Greater energy can be put into the light flash if wire is used.

X-3 ANDREEV, S. I., and VANYUKOV, M. P., "Methods of Shortening Light Flash Duration and Increasing Intensity," VI Internat. Congress on High-Speed Photog, The Hague (1963), p. 166-172.

The authors suggest using an E. W. in series with a gap. The spark in the gap serves as a light source. The result is a flash of less than half the natural period of the discharge circuit. Any light after a restrike is too dim to cause trouble. They also mention that the E. W. may be used directly as a light source.

X-4 BAKER, L., Jr., and WARCHAL, R. L., "Studies of Metal-Water Reactions by the Exploding Wire Technique," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 207-223

Exploding wires were used to study chemical reactions between molten metals and water. Research was directed toward heating maximum quantity of water to an accurately known temperature. Energy was measured by two methods. Accuracy of temperature determination was within 100°C. High-speed motion pictures allowed study of uniformity of heating and average particle diameters. Results indicate E. W. technique is well suited for accurate studies of chemical reactions between metals and non-metallic fluids.

E-17 BARKOW, A. G., KARIORIS, F. G., and STOFFELS, J. J., "X-ray Diffraction Analysis of Aerosols from Exploding Wires," Advances in X-ray Analysis, VI, Plenum Press, New York (1963) p. 210-222

Eb-2 BETTS, R. E., "Development and Functional Characteristics of the XM-6 and XM-8 Squibs," Proc. Elec. Initiator Symposium, Philadelphia, (1963) The Franklin Institute

X-5 BLOXSOM, D. E., Jr., "Use of Capacitor Discharges to Produce High Temperature, High Pressure Air," Jet Propulsion 28, 609-614 (1958)

An electrical spark discharge technique initiated by an E. W. is described, which has been used to heat air to 9000°K and 40,000 psi at close to 100% energy transfer efficiency. The equipment is used to study hot gas dynamics.

X-6 BOHN, J. L., NADIG, F. H., and SIMMONS, W. F., "Acceleration of Small Particles by Means of Exploding Wires," Exploding Wires Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 339-351

Two methods for accelerating small particles by means of "exploding wire" techniques are described. In one case, the wire was confined in a small cylinder with a gun barrel mounted in the cylinder and perpendicular to it. In the second method, the exploding materials was a small cylindrical piece of graphite. In this configuration, the gun barrel was placed at the end of the graphite with the axis in the same direction. Steel spheres of 1 mm diameter were accelerated to velocities of 3.3 km/sec, and small glass beads were given velocities in excess of 7 km/sec.

X-7 BUNTZEN, R. R., "The Use of Exploding Wires in the Study of Small-Scale Underwater Explosions," Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 195-205

Greater similarity in certain aspects to an underwater nuclear explosion is achieved by using a submerged exploding wire than with conventional chemical explosives. This is apparent in the high temperatures attained and in the lack of noncondensable explosion products in the exploding wire model.

A general description of the underwater explosion event and energy partition analysis between bubble formation, shock wave, and thermal radiation is given.

X-8 CHACE, W. G., "Uses of Exploding Wires," Encyclopedic Dictionary of Physics, Vol. 11, pp. 85-88 (1966) Pergamon Press, London.

Description of E. B. W., electroforming, also brief description of use of E. W. as light source, plasma source, source of shock waves, fast switch, chemical synthesis.

J-1 CHACE, W. G., and FISH, C. V., "Exploding Wire Blast Shutter," Appl. Optics 2, 441-443 (1963)

H-4 CHASE, N., HANKIN, N., and WEBB, F. H., Jr., "Instrumentation for Exploding Wire Research," Electronics, p. 43-45 (July 1, 1960)

X-9 CHURCH, C. H., HAUN, R. D., Jr., OSIAL, T. A., and SOMERS, E. V., "Optical Pumping of Lasers Using Exploding Wires," Appl. Optics 2, 451-452 (1963)

Description of experiments in pumping ruby laser with Cu, W, Al, Nichrome wires. W seems best. A small wire "saturates" i.e., its light output does not increase with energy input after a certain value. Wires are less efficient but allow higher pumping rates than flash tubes.

X-10 CHURCH, C. H., HAUN, R. D., Jr., OSIAL, T. A., and SOMERS, E. V., "Optical Pumping of Lasers Using Exploding Wires," Westinghouse Research Lab., Sci. Paper 62-112-259-P1 (July 1962)

Description of experiments with Ruby Laser and Cu, W, and nichrome wires a pump light sources. Voltages 6-20 kV energies up to 16 kJ. Equipment is described. Results given for laser and E. W. light outputs are semi-quantitative. Problems of vapor deposit and pitting are discussed.

X-11 CLINGMAN, D. L., GUBBINS, D. G., and ROSEBROCK, T. L., "The Influence of Electrode Geometry on Rail Accelerator Performance," Gen. Motors, Allison Div. Eng. Dept. Rept. No. 3163 (Jan 1963)

Various rail configurations (twisted, cusp, four square, etc.) were compared with straight 1/4 in. brass rails as an impulse source. None of the new configurations were as good as the straight rails. A pendulum was used as a measuring device.

A-8 CNARE, E. C., "An Exploding Wire as a Fuse for the LASL Capacitor Bank - Zeus," Sandia Corporation SC-4324 (TR), TID-4500 (14th ed) (1959)

X-12 CNARE, E. C., "Exploding Wire Detonation: An Approximate Method of Predicting Exploding Wire Detonator-Capacitor Discharge System Performance," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 185-192

The burst current criterion of exploding wire detonator performance has been combined with the energy balance for an RLC discharge circuit. By introducing certain approximations the initial capacitor voltage required to produce a particular burst current can be calculated. The resulting relations are useful in predicting the performance of detonator-firing set systems.

R-3 CONN, W. M., and DEEG, E. W., "Use of the Solar Furnace as an Intermediate Imaging Source for Attaining Extreme Temperatures for a Short Time," Bull. Am. Phys. Soc. 3, 375 (1958)

E-72 CONN, W. M., "A New Effect Observed in Connection with Electrically 'Exploded' Wires," Nature 169, 150 (1952)

X-13 CONN, W. M., "Use of the Exploding Wire Phenomenon for Research and Development work in Glass Systems," Central Glass and Ceramic Research Institute Bull. 11, 100-105 (1964)

Suggests use of E. W. produced shock waves for fracture analysis of glass. Also recalls use for coating.

X-14 FISH, B. R., ROYSTER, G. W., et al, "Aerosol Physics," Health Physics Division Ann. Prog. Rep. 1963, K. Z. Morgan (ed), ORNL-3492 (1963) p. 185-193

Data on aerosols produced by E. W. method.

X-15 GARBUNDY, M., GOTTLIEB, M., and CONROY, J. J., "Hard Superconducting Films for Exploding Wires," J. Appl. Phys. 34, 3642-3643 (1963)

The authors made superconducting films of niobium and niobium-zirconium by exploding wires in purified noble gases and even air. Wires were 3 cm long × 0.025 cm dia. and exploded with 100 J.

X-16 GERHARZ, R., "Zur Herstellung dunner Aluminiumschicten in kurzen Bedampf zeiten," Z. angew. Physik, 9, 95-98 (1957) (Preparation of Thin Aluminum Films in Short Vaporization Times)

Investigates relation of quality and adherance of Al films to time of depositing, vapor density, and density gradient. Deposits were made from heated W sources, pulsed arcs, and exploding wires and ribbons. Best results in short times and with high vapor gradients. Much better results also if surface is "shadowed" from direct "beam" of the vapor.

U-3 GUENTHER, A. H., "Production of Strong Shocks in Plastics by Ultra-Short Impulsive Loading," Air Force Special Weapons Lab. AFSWC-TDR-62-125 (1962)

X-17 GUENTHER, A. H., WUNSCH, D. C., and SOAPES, T. D., "Acceleration of Thin Plates by Exploding Foil Techniques," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 279-298

A technique for the acceleration of thin plates to high velocities by exploding foils has been developed. These plates, primarily Mylar and Lucite up to 3 in by 3 in. and from a few mils to 1/4 in. thick, are used to produce high-impulse, short-time loading of materials for the purpose of material dynamics at high pressures. Velocities up to 5×10^5 cm/sec have been achieved. A brief description of equipment including the capacitor system, cameras, backlighting, etc., is given, as well as a more detailed description of the construction of the transducer and its characteristics. Methods of velocity determination are described. High-speed photographs of these high-velocity plates are presented.

X-18 GZYLEWSKI, J., LAS, T., BEDNARSKI, T., "Zastosowanie stómych pradow udarowych do hydrodynamicznego i magnetycznego formowania metali," Przeglad Elektrotechniczny 41 (4), 121-125 (1965) (The Application of Steep Pulse Currents to the Electrodynamic and Magnetic Forming of Metals)

Description of and brief discussion of equipment for electroforming and magnetic forming of metals. Some examples are given. The use of E. W. in electroforming is very briefly discussed.

E-98 HALLOWES, J. P., Jr., "Generation of Fast Waveforms," Res. Labs. Quarterly Res. Rev. 17, 88-97 (1958) Army Rocket and G. M. Agency

X-19 HARRAWAY, R. A., "An Exploding Wire Triggered Spark Gap," J. Sci. Instr. 41, 399 (1964)

An atmospheric spark gap triggered by an E. W. placed transverse across the gap is described. It has the advantage of operation over a wide range of voltages without adjustment.

Q-7 HUBER, H., "Technical Specifications of an Exploding Wire Triggered Solid Dielectric-Switch," Stevens Inst. Tech. SIT P-78 (Jan 1963)

A-11 JANES, G. S., and KORITZ, H., "High Power Pulse Steepening by Means of Exploding Wires," Rev. Sci. Instr. 30, 1032-1037 (1959) (Also AVCO Res. Lab. Res. Rept. 50 (1959)

X-20 JONCICH, M. J., and REU, D. G., "Synthesis of Inorganic Binary Compounds Using Exploding Wire Techniques," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1964) p. 353-359

In an exploratory study, E. W. P. has proved to be useful in synthesizing iodides, sulfides, and carbides of magnesium and aluminum. Carbides of zirconium have also been prepared. Chemical combination of the metal and nonmetal took place in all cases; yields have ranged from 20 to 60%. The preparation of anhydrous magnesium iodide, a compound which is extremely difficult to prepare by other means, has received particular attention. Apparatus and procedures are described in some detail. Further applications of E. W. P. to inorganic, organic, and biochemistry are suggested.

X-21 JONCICH, M. J., and VAUGHN, J. W., "Chemistry at 1 Million°K," New Scientist 25, 716 (1965)

Brief, popular, description of use of E. W. for preparing binary compounds. Suggests explosions under various pressures and ambient temperatures, including liquid N_2.

E-105 JONCICH, M. J., VAUGHN, J. W., and KUNTSEN, B. F., "Preparation of Metal Nitrides by the Exploding Wire Technique," Canadian J. Chem. 44, 137 (1966)

M-11 JONES, D. L., and EARNSHAW, K. B., "A Wire Exploder for Generating Cylindrical Shock Waves in a Controlled Atmosphere," NBS Technical Note No. 148 (Feb 1962)

X-22 JONES, I. R., and WUERKER, R. F., "Generation of High Power Radio-Frequency Pulses by Means of an Exploding Wire Technique," Rev. Sci. Instr. 32, 962-963 (1961)

Uses an E. W. to "open" the circuit in a typical ringing circuit damped oscillator. The RL circuit rings during the dwell in the E. W. Gets 6 μsec oscillation, characteristic of the RL circuit and with a Q of 88. Peak rf current is 7200 amps.

E-106 KARIORIS, F. G., and FISH, B. R., "An Exploding Wire Aerosol Generator," J. Colloid Sci. 17, 155-161 (1962)

X-23 KARIORIS, F. G., and WOYCI, J. J., "X-ray Investigation of Aerosols from Wires Exploded in Nitrogen," XII Ann. Conf. on Appl. of X-ray Analysis (Aug 1963) p. 240-251

Study of the aerosol produced by exploding wires in nitrogen at atmospheric pressure. Shows some nitrides, some metals. Some of the nitrides were apparently very easily analyzed.

X-24 KARIORIS, F. G., and YOUNGBLOOD, J. W., "Aerosol Generator," in Health Physics Annual Prog. Rpt. 1961, K. Z. Morgan (ed) ORNL-3189, p. 227-229 (1961)

A description of an E. W. generator for aerosols, and some data on the results.

E-107 KARIORIS, F. G., FISH, B. R., and ROYSTER, G. W., Jr., "Aerosols from Exploding Wires," Exploding Wires, Vol. II, Chace and Moore (eds) Plenum Press, New York (1962) p. 299-311

X-25 KELLER, D. V., and PENNING, J. R., Jr., "Exploding Foils - The Production of Plane Shock Waves and the Acceleration of Thin Plates," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 263-277

Electrical explosion of thin metal foils has been used to induce shock waves in solids. The foil is either placed in direct contact with the solid, or it is used to accelerate a thin-plate projectile to high velocity which strikes the target. Pressures to 10 kilobars have been obtained by the direct method. Mylar plates 2 in. square have been accelerated to 0. 4 cm/μsec. This gives pressures to 80 kilobars. A 2 in. square of Al foil explodes simultaneously over its area to within 10^{-7} sec. An 80 kilobar pulse of 0. 1 μsec duration is possible

E-113 KESSLER, M., "Conception and Installation of an Electrical High Energy Discharge Unit," Watertown Arsenal Lab. WAL TN 126 1/1 (Oct 1962)

X-26 KLEIN, A. F., "Some Results Using Optical Interferometry for Plasma Diagnostics," Phys. Fluids 6, 310-311 (1963)

The light sources for the Mach-Zehnder Interferometer was a 0.005 W wire. Data on the light source are given.

X-27 KONSTANTINOV, B. P., ZIMKIN, I. N., STEPANOV, M. I., and SHESTOPALOV, L. M., "Hardening of Steel Surface by Wire Explosion," Fizika metallov i metallovedeniye 22, 157-158 (1966)

Copper or steel wire, 0.38 - 0.4 mm dia. and 40-50 mm long, placed 10 mm above the face of a cylindrical U8A steel specimen was exploded. The surface microhardness increased from 170-200 Kg/mm^2 to 950-1200 Kg/mm^2, the average thickness of the layer was 20-30μ. X-ray diffraction showed up to 70% austentite, the rest ferrite, no significant marstenite.

X-28 KUL'GAVCHUK, V. M., "Producing Powerful Radio Pulses by the Electric Explosion of Metal Wires," Pribary i tekhnika eksperimenta No. 1 132-137 (1965)

An ordinary ringing circuit is actuated by the explosion of a wire in the line carrying current to the coil. The very high current in the coil gives high current in the ringing circuit. The author studies effect of wire parameters on the ringing current.

X-29 LA COSS, W. D., "A Qualitative Study on an Exploding Wire Fuse," Sandia Corp. SCTM 145-61 (14) (Aug 1961)

A study of an exploding wire fuse was undertaken in an effort to develop basic concepts of normal operating fuse criteria that will apply to capacitor energy storage systems. Topics covered include exploding wire characteristics, fusing action and capacitor bank compatibility, methods of heat dissipation for a fuse during normal operation, and methods to determine repetition rate boundaries.

Eb-6 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires: VIII Survey to Determine Explosives Capable of Initiation at Moderate Voltage Levels," Nav. Ord. Lab. NOLTR 65-127 (1966)

Eb-14 LEOPOLD, S., "Bridgwire Diameter Design Considerations for an EBW Initiator," Proc. Elect. Initiator Symposium, Philadelphia, (1963) The Franklin Institute p. 23-1 to 23-13.

Eb-13 LEOPOLD, H. S., "Initiation of Explosives by Exploding Wires," USN Ord. Lab. NOLTR 63-244 (1964).

F-3 LEWIS, M. R., and SLEATOR, D. B., "Exploding Wire Light Source for High Speed Interferometry," Ballistic Res. Lab. Memo Rep. No. 975 (Feb 1956)

P-10 LOGINOV, V. A., "The Production of Electronic Band Spectra by the Exploding Wire Method," Optika i Spektroskopiya 16, 402-403 (1964) Trans in Optics and Spectroscopy 14, 220-223 (1964)

E-137 MAHIEUX, F., "Reactions Chimique par explosion de fils metalliques. Synthese de l'hexafluoroplatinate de xenon," Compte Rend. 257, 1083-1086 (1963) (Chemical Reactions Brought About by the Explosion of Metal Wires)

X-30 MAHIEUX, F., "Sur l'hexafluoroplatinate de xenon obtenu par explosion de fil," Compte Rend 258, 3497-3498 (1964). (Concerning hexafluoroplatinate obtained by the 'explosion of a wire)

The authors reexamine the product formed by explosion of Pt wire in gas mixture F:Xe::6:1 by volume. They had previously characterized it Pt Xe F_6. From results of present work they now suggest $(Pt\ F_6)_2$ Xe.

Q-9 MAISONNER, C., LINHART, J. G., and GOURLAN, C., "Rapid Transfer of Magnetic Energy by Means of Exploding Foils," Rev. Sci. Instr. 37, 1380-1384 (1966)

X-31 MARCUS, R. A., "Application of the Exploding Wire Technique in Photochemistry," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959), p. 307-314

The short duration and high actinic value of light from E. W.'s make them a desirable light source for certain photochemical reactions. Various relations are discussed.

A-14 MARSHAK, I. S., "On the Practical Application of Exploding Wires," Optika i Spectroskopia 10, 801-804 (1961), Trans. in Optics and Spectroscopy 10, 424-426 (1961)

X-32 McFARLANE, H. B., "A High-Voltage, Quick-Acting Fuse, to Protect Capacitor Banks," Exploding Wires, Vol. I, Chace and Moore (eds) Plenum Press, New York (1959) p. 324-344

A high-voltage fuse designed to protect capacitor banks is described. Design criteria are given and a possible mechanism is theorized.

F-4 MEINERS, D., BORTFELDT, J., WEBER, W., WITTIG, L., "Ein Verfahren Zur Messung des Absorptionskoeffizienten in inhomogenen und instationären Plasmasäulen mit hoher optischer Schichtdicke," (A Method for Measuring the Absorption Coefficients in nonhomogeneous and nonstationary plasma columns with optical density), in Forschungsbericht K66-27, Bundesministerium für wissenschaftliche Forschung (Juli 1966) (Research Report K66-27, Federal Ministry for Scientific Research (July 1966) (Germany)

E-161 NASILOWSKI, J., "Elektromagnetyczne sciskanie odorobnionego przewodu wiodqcego prqd.," (Electromagnetic Compression of an Isolated Wire Through Which an Electric Current is Flowing) Przeglad Elektrotechniczng 38, 152-154 (1962)

S-5 O'KEEFE, J. D., and SCULLY, C. N., "Axial Flow from a Radially Confined Electrically Exploded Cylinder," Exploding Wires, Vol. III, Chace and Moore (eds) Plenum Press, New York (1864) p. 211-222

F-6 OSTER, G. K., and MARCUS, R. A., "Exploding Wire as a Light Source in Flash Photolysis," J. Chem. Phys. 27, 189-192 (1957)

Eb-20 PELPHREY, J., "Development of an Exploding Bridgewire Propellant Ignition System for Davy Crockett," Proc. Elec. Initiator Symposium, Philadelphia, 1963, The Franklin Institute

X-33 SCHERRER, V. E., "An Exploding Wire Hypervelocity Projector," Exploding Wires, Vol. II, Chace and Moore (eds), Plenum Press, New York (1962) p. 235-244.

A gun type accelerator is used to produce hypervelocities. A wire or foil is exploded as propellant, a mass of water seals the breach to a glass or plastic capillary as the barrel. Projectile velocities to approx. 50,000 ft/sec and gas velocities to 100,000 ft/sec have been obtained. Equipment and description are described.

X-34 SCHERRER, V. E., "Effects of Hypervelocity Impacts on Materials," Tech. Doc. Rept. No. ASD-TDR-62-762 (Aug 1962)

A novel exploding-foil gun is described which routinely accelerates small particles (mass 1-100 mg) to velocities up to 60,000 ft/sec when coupled to a slow capacitor energy storage system. When the gun was efficiently coupled to a fast-capacitor energy storage system, a single, solid particle was accelerated to a velocity of 102,000 ft/sec. A detailed study of various particles impacting quasi-infinite lead targets was made, and preliminary results are given for particle velocities from 7,000 to 40,000 ft/sec. These results indicate a deep penetration phenomenon for a particle velocity of 15,000 ft/sec. If similar phenomena are observed in materials of interest in space vehicle construction, the results will be very important in the design of such structures. Plans are presented for expanding the hypervelocity facility and improving its performance in the future.

X-35 SCHIFF, D., "Bonding Experiments with Exploding Foils," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 283-287

Various materials otherwise difficult to join may be bonded by clamping with a Ta foil between them and exploding the foil. Quartz may be so bonded, as well as ceramics.

X-36 SPANGLER, C. W., LOTT, S. K., and JONCICH, M. J., "Acetylene Formation from Graphite Under Exploding Wire Conditions," Chem. Communications 842-843 (1966)

It was found by tracing with deuterium that in the explosion of graphite in hydrogen the most likely mechanisms are through methylene (CH) free radical, e.g.,

$C + H_2 \rightarrow (CH) + H$
$2(CH) \rightarrow CH \equiv CH$
$(CH) + H_2 \rightarrow CH_3$

E-190 STAMBLER, I., "Exploding Wires, Likely to Find Many Uses," Space/Aeronautics p. 48-51 (Sept 1960)

X-37 STARR, W. L., "Exploding Wire Plasma Accelerator," Exploding Wires, Vol. I, Chace and Moore (eds), Plenum Press, New York (1959) p. 365-373

A device that accelerates plasma from E.W. to 8×10^6 cm/sec is described. Impulse is 10^3 dyne-sec. Measuring system as well as E.W. system is described.

E-192 STARR, W. L., and NAFF, J. T., "Acceleration of Metal Derived Plasmas," Lockheed Tech. Memo LMSD-288240 (Dec 1959)

Eb-22 STEPPE, A. J., and MASSEY, J. M., "Discourse on M.T.L.-I-23659 (WEP)," Proc. Elect. Initiator Symposium, Philadelphia, (1963) The Franklin Institute

Eb-23 STRESAU, R. H., and HILLYER, R. M., "Exploding Bridgewire Initiation of RDX with 50 Millijoules," Proc. Elect. Initiator Symposium, Philadelphia (1963) The Franklin Institute

Q-11 TATIBANA, F., "Triggering Electrical Breakdown in High Vacuum by Wire Explosion," J. Appl. Phys. (Japan) 30, 71-72 (1961)

M-24 TODD, J., Jr., "A Photographic Study of Sources of Spherical Shock Waves," SCTM-242-54 (51) (Nov 1954)

X-38 WAGNER, H. J., and BOULGER, F. W., "High Velocity Metalworking Processes Based on the Sudden Release of Electrical Energy," Battelle Memorial Institute, Defense Metals Information Center, DMIC Memo 70 (Oct 1960)

Very brief description of: (1) Spark, (2) E.W., (3) Magnetic forming listing advantages and disadvantages and a bibliography.

U-10 WUNSCH, D. C., SOAPES, T. D., and GUENTHER, A. H., "Acceleration of Thin Plates by Exploding Foil Techniques," AF Special Weapons Laboratory Report AFSWC-TDR-61-75 (Jan 1962)

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13. ABSTRACT

This bibliography includes abstracts of reports on the exploding conductor (exploding wire) phenomenon published from 1774 through 1966. There is also some coverage of important papers in adjacent areas of spectroscopy and instrumentation. Arrangement is by subject group, alphabetically by authors.

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